



Toward

Integrated

Environmental

Decision-Making

The Science Advisory Board (SAB) of the U.S. Environmental Protection Agency is a body of independent experts who provide advice to the EPA Administrator on scientific and engineering issues. The SAB was established in its present form by the Congress in 1978. The SAB's approximately 100 members and more than 300 consultants include scientists, engineers, and other specialists drawn from a broad range of disciplines—physics, chemistry, biology, mathematics, engineering, ecology, economics, medicine, and other fields. Members are appointed by the Administrator to two-year terms. The SAB meets in public session, and its committees and review panels are designed to include a diverse and technically balanced range of views, as required by the Federal Advisory Committee Act (FACA).

The Board's principal mission is to review the quality and relevance of the scientific information being used to support Agency decisions, review research programs and strategies, and provide broad strategic advice on scientific and technological matters. In addition, the Board occasionally conducts special studies at the request of the Administrator to examine comprehensive issues, such as anticipating future environmental problems and developing new approaches to analyze and compare risks to human health and the environment.

Toward Integrated Environmental Decision-making

U.S. Environmental Protection Agency

Science Advisory Board

Integrated Risk Project

August 2000



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

August 18, 2000

OFFICE OF
THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

EPA-SAB-EC-00-011

Honorable Carol M. Browner
Administrator
U.S. Environmental Protection Agency
Washington, DC 20460

Subject: Final SAB Report, *Toward Integrated Environmental Decision-making*

Dear Ms. Browner:

It is our pleasure to send you the accompanying final report, *Toward Integrated Environmental Decision-making*, from the Science Advisory Board's (SAB) Integrated Risk Project. This report marks the completion of the most complex and challenging activity ever undertaken by the Board, involving more than 50 natural scientists, economists, and social scientists working together over more than three years. The report has been subjected to a public peer review process in accordance with the Agency's Peer Review Policy, and we acknowledge the inputs and insights of the peer reviewers.

Originally conceived by some as a simple "updating" of the SAB's *Reducing Risk* report, the Integrated Risk Project (IRP) challenged the SAB to extend far beyond that 1990 product. *Reducing Risk* effectively legitimized the notion that larger environmental risks can be distinguished from smaller risks on the basis of scientific criteria. Some advocates of the IRP on Capitol Hill and in the Agency envisioned that the SAB would go further in today's report and develop a ranked list of environmental risks, based not only on consensus scientific insights but on consensus social values as well! Suffice it to say that this grand view was neither the SAB's intention nor its product.

Instead, the SAB has developed a conceptual framework or vision for "the next step" in environmental protection in this country. The first step was taken in the 1970s when there was broad public consensus regarding environmental problems and their sources. The second step was taken when the Agency adopted the risk assessment/risk management paradigm in the 1980s to support risk-based decision-making. Building on Agency actions and several external reports generated in the 1990s, the SAB now proposes a

Framework for Integrated Environmental Decision-making that describes how a broader array of considerations and participants can and should affect environmental decision-making in the future.

One of the principle features of “the next step” is the involvement of a wider range of people — and their perspectives/values — in the decision-making process. The Framework also emphasizes use of the best science (both natural and social sciences) to assess cumulative, aggregate risks; to consider a broader range of options for managing or preventing risks; to make clear the role of societal (public) values in deciding what to protect; to clarify the trade-offs (including costs and benefits) associated with choosing some management scenarios and not others; and to evaluate progress toward desired environmental outcomes.

To be sure, the Framework is not a “turn-key” operation that needs only to be implemented. In fact, much work remains to be done. The IRP took the SAB, and the Agency, into unfamiliar territory, involving research literatures in behavioral decision science and decision theory with which we have had limited past experience. The effort has emphasized the importance of expanding the scope of expertise—both in the SAB and the Agency—into these important domains. The project also has emphasized the importance of adopting an interdisciplinary approach that combines deep understanding of environmental science with theory and empirical methods in behavioral and decision science.

If the journey toward more integrated environmental decision-making is to be successful, the Agency will need to undertake a significantly expanded effort in developing improved tools and guidance that have been vetted with real problems. Specific focused research is needed on problems that range from improving methods for informed synthesis and elicitation of public environmental values, to tools and procedures that support improve characterization and treatment of uncertainty, reasoned science-based deliberative processes, and the evaluation of multi-dimensional risks.

We note that the seeds of integrated environmental decision-making as described in the report already have been planted in the Agency. New technologies and systems are being instituted at EPA that can work together to nourish and encourage those seeds to sprout and grow. Prototypic tools have been devised as a part of this SAB exercise that should be explored and, as appropriate, further developed through research and applications to real problems in environmental decision-making. While the report charts a valuable future direction for the Agency, a number of specific paths can lead to the desired destination. There can be no substitute for a thoughtful strategy of experimentation worked out in the specific settings of different environmental problems.

As noted in the final section of the report, “In some ways, the Board has been true to the old adage that one’s goal should exceed one’s grasp. That is, the goal of this project — to articulate a complete and rational method for including all aspects of integrated environmental decision-making in a single process — has exceeded the SAB’s grasp. In fact, it is likely that that goal will never be reached to everyone’s satisfaction.

And yet, the Framework that was developed during the course of the project, clearly points to the direction in which “the next step” of environmental decision-making should go. The efforts of the individual Subcommittees can be examined for further insights about how the Agency might — or might not — make additional progress in that direction. In any event, there is enough direction and more than enough challenge in this report to keep the Agency, and others interested in the next step of environmental decision-making, productively active for some time to come.” The challenges of improving and better integrating environmental decision-making are considerable, but the end result should be worth the effort.

We look forward to discussing this report and your reaction to it at an upcoming SAB Executive Committee meeting.

Sincerely,

A handwritten signature in black ink, appearing to read "Granger Morgan". The signature is fluid and cursive, with the first name "Granger" being more prominent.

Dr. M. Granger Morgan, Acting Chair
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A handwritten signature in black ink, appearing to read "Genevieve M. Matanoski". The signature is elegant and cursive, with the first name "Genevieve" being the most distinct part.

Dr. Genevieve M. Matanoski, Chair
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NOTICE

This report has been written as part of the activities of the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency and, hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the Federal government, nor does mention of trade names or commercial products constitute a recommendation for use. The SAB members and consultants who participated in the activities that resulted in this report did so as individuals, rather than as representatives of their employing organizations.

This particular project was conducted at the request of the EPA Administrator and addresses a broader range of issues and concerns than most SAB reports. Consequently, many of the recommendations in this report have more of a policy orientation than is usually the case.

Distribution and Availability: This Science Advisory Board report is provided to the EPA Administrator, senior Agency management, appropriate program staff, interested members of the public, and is posted on the SAB website (www.epa.gov/sab). Information on its availability is also provided in the SAB's monthly newsletter (*Happenings at the Science Advisory Board*). Additional copies and further information are available from the SAB staff.

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1. INTEGRATED ENVIRONMENTAL DECISION-MAKING

1.1 Environmental Integration: The Next Step

Environmental protection in the United States has progressed through at least two major steps. The first step characterized the early days of the 1970s when the Environmental Protection Agency (Agency) enjoyed both a public consensus and Congressional mandates about what needed to be done; e.g., clean up the air and make the waters fishable and swimable. A second, more sophisticated step was taken in the mid-1970s and honed in the 1980s and 1990s when the “risk assessment/risk management (RA/RM) paradigm,” first proposed by the National Research Council (NRC, 1983), was adopted and implemented by the Agency. The RA/RM approach has been especially useful in those instances in which the damage and/or danger is not immediately evident and some data and analysis are necessary around which to form a consensus for action.

In this document, the Science Advisory Board (SAB) describes the outlines of “the next step” in environmental decision-making. The SAB presents here a broad conceptual way of thinking about environmental problems that responds to criticisms of the fragmented approaches that dominate current national strategies for protecting human health and the environment. At the core of this concept is integrated thinking about complex environmental problems, integrated resources and analyses to address the problems as they occur in the real world, and integrated input from the public and interested and affected parties. Integrated decision-making is a natural next step

from both prior SAB and Agency projects that considered individual risks in relation to each other. In addition, it builds upon the significant success that has grown from many of the reinvention and reorganization activities in the Agency during the 1990s.

As a result of conducting the Integrated Risk Project (IRP), the SAB is proposing a conceptual Framework for Integrated Environmental Decision-making (IED) to guide the Agency in the continuing evolution of environmental decision-making. In addition, IRP subcommittees have described a number of tools and approaches that, with further development and application, may provide a means of developing some of the information and analyses suggested by the Framework. However, the SAB is not presenting a “turn-key” procedure that will solve all of the problems associated with the current decision-making environment. Rather, the report points to new directions that will broaden the decision-making process in terms of both the factors that should be considered and the parties who should be involved in making and evaluating environmental decisions. It is left to the Agency and others to apply the conceptual Framework to specific problem sets, and thus to develop and implement practical strategies and operations that will realize the potential benefits of integrated environmental thinking.

The evolution in environmental decision-making called for in this report is not meant to detract from past environmental accomplishments nor to replace existing regulatory processes and requirements. The concept of an integrated

Prioritizing and managing risks pollutant by pollutant and medium by medium can be inefficient both in reducing the major burdens of environmental impacts on human health and ecosystems and in allocating society's resources...

Framework is intended to be further developed, tested, and used in conjunction with existing environmental management approaches to strengthen the risk reduction programs now being implemented and improve environmental management in the future.

1.2 The Call for Integrated Decision-Making

Environmental decision-makers currently draw upon an eclectic mixture of data, tools, and analyses to inform their decisions: ecological and human health risk assessment; benefit-cost and cost-effectiveness models; expanded risk communication and public participation; and measures for monitoring the results of the decisions themselves. Although these contributions are essential inputs for decision-making, they have often been applied unevenly and to relatively narrow issues. In the area of human health risks, for example, assessments often have been framed around single stressors or classes of stressors in relatively specific exposure situations. The deficiencies of such highly focused assessments are increasingly apparent; they sidestep the complexities, interrelationships, and subtleties of environmental problems as they actually confront society. Thus, a number of recent studies have urged the Agency to begin to address environmental issues in a more integrated way (e.g., NAPA, 1995; Presidential and Congressional Commission on Risk Assessment and Risk Management, 1997).

Much of the fragmentation in EPA's approach to the control of environmental problems has its roots in the statutory framework that guides the work of the Agency. From its formation in 1970, the EPA has been given responsibility for implementing a number of environmental statutes that mandate targeted actions to control specific pollutants in specific media (cf., Clean Air Act language regarding particulates in air) or specific routes of exposure (cf., Safe Drinking Water Act language

regarding priority pollutants in drinking water). The focus on assessing and controlling chemical contaminants pollutant by pollutant in single media has resulted in a regulatory system that is neither systematic nor comprehensive. Nonetheless, the system has been largely successful in controlling many of the targeted pollutants and has provided a strong national underpinning for an effective environmental protection program comprised of federal, state, and local controls.

Despite these successes, there is a growing consensus, both within and outside the Agency, that a more integrated approach to environmental management is needed. Prioritizing and managing risks pollutant by pollutant and medium by medium can be inefficient both in reducing the major burdens of environmental impacts on human health and ecosystems and in allocating society's resources in the face of multiple demands on limited budgets. Further, that piecemeal approach ignores the integrated manner in which hazards usually occur. Of still greater concern is the possibility that such a fragmented approach may cause us to overlook significant environmental problems while we busy ourselves with comparatively minor improvements that contribute little to the overall protection of human health and ecosystems.

In some instances, current statutes and regulations prevent the Agency from considering all relevant risk, benefit-cost, or other information. Further, as pointed out in a recent NAPA report, there are "no established criteria that the Agency might use to set priorities that cut across statutory lines" (NAPA, 1995). The SAB views the issue of statutory integration as a policy discussion and outside the bounds of the present study. However, the Board believes that even within the current statutory framework, there are numerous opportunities for a more holistic assessment of risks and risk management options. There are also opportunities for more inclusive decision-making approaches, both in terms of participation in the

process by groups with diverse perspectives on the issues and in terms of the focus of such reviews, e.g., sectors, communities, industries, ecosystems, and special groups within the population. In addition, there is a growing sense that a broader range of factors should influence a given environmental decision and that such factors should be more systematically considered and articulated. These factors include economic consequences (often expressed in terms of benefits and costs) and concerns of the public as expressed in their underlying values.

Answers now are needed to questions that were not asked when the predominantly pollutant-by-pollutant regulatory system was first established. These new questions focus on, for example, cumulative risks to sub-populations or particular geographic areas, the role of public involvement in environmental decision-making, and the balance between present and future consequences of decisions. The proposed Framework for making integrated environmental decisions should help direct research and thinking about these issues in a way that will generate answers to such questions.

New questions require new approaches to technical analyses and public policy-making.

What are the most serious environmental risks facing children, or the elderly, across the nation?

What are the factors that pose an aggregate set of risks to everyone living in a particular geographic area?

What are the interrelated risks to human and ecological health associated with a particular industrial sector?

Of all the risks affecting a geographic area or subset of the population, which are most serious, and which are we most capable — economically, technologically, and politically — of limiting?

How can we achieve the right balance between protecting the health and the welfare of present and future generations and assure ecological security for the long term?

What combinations of risk management tools — regulatory and non-regulatory, technological and non- technological — can be used in concert to achieve environmental goals in particular communities or ecosystems?

How can we measure our progress in solving integrated environmental problems and reaching our long-term goals: protection of ecological integrity, human health, and quality of life?

How can worthy, but competing, individual and group goals be accommodated?

What is the distribution across the population of benefits and costs associated with environmental risks and their possible management?

What is the appropriate role for public involvement in the assessment and management of environmental risks?

...even within the current statutory framework, there are numerous opportunities for a more holistic assessment of risks and risk management options.

1.3 Signs of Progress

In a 1983 publication entitled *Risk Assessment in the Federal Government: Managing the Process* (NRC, 1983), commonly referred to as the “Red Book,” an NRC panel laid out the elements of RA/RM using terminology that came to be the standard. These concepts were adopted by the Agency in 1984 and have formed the basis for much of the Agency’s action to this day. In summary, the NRC panel described the four steps of risk assessment as hazard identification, dose-response assessment, exposure assessment, and risk characterization, where the latter was defined as “the estimated incidence of the adverse effect in a given population.” In addition, the panel stressed the scientific basis for risk assessment and the need for both quantitative and qualitative expressions of risk. Risk management was viewed as “a decision-making process that entails consideration of political, social, economic, and engineering information with risk-related information to develop, analyze, and compare regulatory options and to select the appropriate regulatory response.”

The Red Book was extremely useful in articulating the risk assessment process and its relationship to risk management. The paradigm was expressed, however, in terms of single agents and single health effects in humans. Since that time, the Agency has developed risk assessment guidelines to address a number of human health endpoints (i.e., cancer, reproductive and developmental toxicity, and neurotoxicity), as well as guidelines for exposure assessment. In addition, the Agency has taken steps to consider more integrated exposure scenarios; e.g., multi-route exposures to a) mixtures of chemical agents associated with Superfund sites (U.S. EPA, 1989), b) a fuller range of combustion emissions (EPA, 1990; 1993a), and c) multiple pesticides, in response to the Food Quality Protection Act.

The Agency also has made significant progress in adapting the Red Book paradigm to ecological

risk assessment. In 1992, the Agency released its *Framework for Ecological Risk Assessment* (U.S. EPA, 1992) which used the term “characterization of ecological effects” to include both hazard identification and exposure assessment. The Framework also added a) an explicit Problem Formulation phase prior to the analysis of exposure and effects in order to emphasize the importance of articulating the problem and b) a plan for analyzing and characterizing risk prior to conducting specific risk analyses. The resulting framework contained three phases: Problem Formulation, Analysis, and Risk Characterization. An expanded discussion of ecological risk assessment principles and approaches was subsequently provided by the Agency in final *Guidelines for Ecological Risk Assessment* (U.S. EPA, 1998). The guidelines note that “although ecological risk assessments provide critical information to risk managers, they are only part of the environmental decision-making process” (U.S. EPA, 1998). In addition to assessing the relationship between a particular stressor and a particular effect, the ecorisk guidelines set the stage for considering multiple effects (including cascading effects) associated with a single stressor or source, as well as multiple causes of an observed effect or change in ecological condition. The Agency has already applied the ecological risk assessment paradigm to five watershed cases, which included developing a conceptual model for each that relates various stressors and effects (for discussion, see SAB, 1997).

Four additional Agency developments, though not reviewed by the SAB for scientific content, merit mention here: a) guidance and support for comparative risk analysis; b) extra-statutory approaches to environmental protection; c) guidance on planning and scoping for cumulative risk assessment; and d) inclusion of interested and affected parties in decision-making.

First, Comparative Risk Analysis (CRA) has been defined by the Agency as “both an analytical process and a set of methods used to systemati-

cally measure, compare, and rank environmental problems” (U.S. EPA, 1993b). The Agency, in its *Unfinished Business* report (U.S. EPA, 1987), and the SAB, in *Reducing Risk* (SAB, 1990), engaged in comparative risk analyses. In its 1990 report, the Board concluded that it was possible, on a scientific basis, to distinguish between large risks and small risks using a set of technical criteria. In the years that followed, the Agency promoted the wide use of CRA as a process for setting priorities by considering multiple stressors and multiple types of risks within specific regions, such as cities or states, or for the nation as a whole. Comparative risk analysis is intended principally as a policy-development and broad resource-allocation tool. In contrast to *Unfinished Business* and *Reducing Risk*, however, state and local-level comparative risk analyses have highlighted the role of the public and stakeholder groups, in addition to the scientific/technical community, in defining risk priorities. Support for broader inclusion of public values in decision-making is a theme that has been echoed by a number of recent reports (e.g., NRC, 1996; Presidential/Congressional Commission on Risk Assessment and Risk Management, 1997).

Second, during the 1990s, the Agency experimented with a number of approaches to re-inventing environmental protection, including greater use of community-based decision-making, voluntary cross-media emissions reductions, integrated environmental agreements with states, and voluntary regulatory reform efforts with an array of stakeholders (U.S. EPA, 1999).

Third, the Agency has issued cumulative risk guidance that directs program offices to “consider a broader scope that integrates multiple sources, effects, pathways, stressors, and populations for cumulative risk analyses in all cases for which relevant data are available” (U.S. EPA, 1997a). The cumulative risk guidance also notes that on-going Agency efforts to involve stakeholders “will provide the solid basis for engaging interested and

affected parties in risk assessment and risk management issues.”

Fourth, the Agency has made progress in recent years in including interested and affected parties in the decision-making process. A recent description of one of these processes—regulatory negotiation in the microbial disinfection and disinfection byproducts rules—can be found in Pontius (1999).

Although the SAB has not reviewed the role and adequacy of the science being used in the planning and evaluation of these activities, these endeavors signal movement in the Agency toward more integrated and inclusive methods of environmental decision-making. These experiments, however, do not yet represent the mainstream of EPA’s efforts.

1.4 Scope of the Project

It is in this atmosphere that the SAB undertook the task of revisiting its 1990 report, *Reducing Risk*, to update and extend the thinking about how science can best inform the decision-making process. The Charge to the SAB from the Agency included requests to update the risk rankings in *Reducing Risk* using explicit scientific criteria and the judgments of SAB panel members; identify risk reduction opportunities and strategies; identify uncertainties and data quality issues associated with the risk rankings; assess costs and benefits of risk reduction options; and propose a new framework for assessing the value of natural resources to society.

The initial charge also included a request that the SAB explore techniques and criteria for identifying emerging risks. However, the SAB concluded that its report, *Beyond the Horizon: Using Foresight to Protect the Environmental Future* (SAB, 1995) provided criteria and suggestions germane to this charge question and so did not elaborate further on future risks as part of the project.

...the SAB concluded that it could best assist the Agency not by developing lists of risk priorities with associated risk reduction options, but by investigating approaches that the Agency might use for developing such priorities.

After careful consideration of the Charge and discussion with Deputy Administrator Fred Hansen, the SAB concluded that it could best assist the Agency not by developing lists of risk priorities with associated risk reduction options, but by investigating approaches that the Agency might use for developing such priorities. In addition, the SAB hoped to place the various technical analyses within the broader decision-making context. Subcommittee Charges

The project, known as the **Integrated Risk Project (IRP)**, was guided by a Steering Committee (SC) and five specialized Subcommittees who began work in Fiscal Year 1996. The Subcommittees and their respective charges were as follows:

- a) **The Steering Committee (SC)**, chaired by Dr. Genevieve Matanoski, set the overall direction for the project by defining scope and timetables. The SC met periodically over the course of the project to: (1) assess the progress and direction of the subcommittees; (2) ensure that the results could be integrated into a comprehensive decision process for identifying current and future environmental risks; and (3) review options for reducing risks in a holistic context. The SC's efforts were designed specifically to illustrate the relationship among the various factors influencing risk management decisions; e.g., technical assessment of the risks and risk reduction options, economic considerations, equity considerations, and so forth.
- b) **The Ecological Risks Subcommittee (ERS)**, chaired by Dr. Mark Harwell, was charged with assessing and ranking risks to ecosystems at the national scale, and suggesting ways in which the risk ranking methodology could be applied at smaller geographical scales; e.g., regional, state, or local. The group was also asked to explore commonalities and differences with the Human Exposure and Health

Subcommittee (HEHS) methodology, with the aim of integrating the two ranking schemes.⁷

- c) **The Human Exposure and Health Subcommittee (HEHS)**, co-chaired by Drs. Joan Daisey and Bernard Weiss, was charged with developing a methodology for assessing and ranking risks to human health, considering ways in which an integrated risk ranking could be produced that includes both cancer and non-cancer risks, and test the methodology for a limited set of environmentally mediated health issues. The Subcommittee was also asked to explore commonalities and differences with the ERS methodology.⁸
- d) **The Risk Reduction Options Subcommittee (RROS)**, co-chaired by Dr. Wayne Kachel and Ms. Marcia Williams, was charged with developing a methodology for selecting an optimal set of risk reduction options with due regard for the human health and ecological risks (defined in terms of risks associated with environmental stressors, locations, or exposure/transport media). The Subcommittee illustrated the methodology by applying it to a small set of example problems.⁹
- e) **The Economic Analysis Subcommittee (EAS)**, chaired by Dr. Paul Portney, was charged with assessing current methods for estimating costs and benefits associated both with the implementation of risk reduction

⁷ The work of the ERS will result in a separate SAB report from the Board's Ecological Processes and Effects Committee.

⁸ The work of the HEHS is summarized in a Working Paper. In addition, the Agency is exploring further development of the prototypic Internet-based tool created in the course of the project.

⁹ The work of the RROS will result in a separate SAB report from the Board's Environmental Engineering Committee.

strategies and with allowing risks to go unaddressed. The EAS was also asked to consider those aspects of the “net benefits” equation that cannot easily be monetized.¹⁰

- f) **The Valuation Subcommittee (VS)**, co-chaired by Drs. Alan Maki and Milton Russell, was charged to consider a new framework for assessing the value of ecosystems to humans, including ecological services and environmentally mediated health and quality of life values. The work of the VS was intended to provide a wider societal view of risk and risk reduction options than that derived from science-based risk assessments and current methods of economic analysis.¹¹

Over the course of the project, the SC and subcommittees held over 25 public meetings and teleconference calls. Although most of these

meetings were held in Washington, D.C., public sessions were also held in Berkeley and San Francisco, CA; Atlanta, GA; New Orleans, LA; and Baltimore, MD. While the bulk of the Subcommittee work was completed in FY 1998, the SC has continued its work of producing a synthesis report, subjecting it to peer review, and responding to comments from the reviewers.

This report contains several sections. Section 2 synthesizes much of the SAB’s deliberations into a conceptual Framework for making integrated environmental decisions. Section 3 describes six of the major elements that contribute to the Framework, identifying specifically the information/tools that are already available and the areas in which additional work is particularly needed. The major recommendations of the SAB are laid out in Section 4. In the closing Section 5, the SAB briefly reviews some of the “lessons learned” in the course of carrying out the IRP.

¹⁰ The work of the EAS will result in a separate SAB Backgrounder that provides an introduction to benefit-cost analysis, its strengths, and its limitations.

¹¹ The work of the VS is summarized in a Working Paper that could serve as input to an SAB/Agency Workshop to explore the issue further with a broader range of participants.

2. A PROPOSED CONCEPTUAL FRAMEWORK

2.1 Overview of the Framework

The approach to integrated environmental decision-making that emerged from the SAB's deliberations is captured in the conceptual Framework for Integrated Environmental Decision-making (IED) in Figure 1. The IED Framework recognizes that risks often are experienced simultaneously and are cumulative (i.e., additive, synergistic, and/or antagonistic); that efforts to manage one risk may have impacts — positive or negative — on other risks; that benefit-cost scenarios may be affected by the scope of the problem definition; and that values deliberation is essential to the development of environmental decisions.

As illustrated in Figure 1, the Framework lays out a series of straightforward questions. What are the most important environmental risks? What are our environmental goals? What are the best risk reduction opportunities? How can we achieve our goals and objectives? How will we know whether or not we are meeting our goals? What modifications in our approach are needed to improve environmental results? Are we meeting our objectives? Is the nature of the problem changing? Finding answers to these fundamental questions requires application of scientific and technical assessment and analysis techniques, as well as political, policy, and values-driven choices. By fostering a more integrated look at environmental goals and priorities, the Framework should help us to make choices not only about which actions to take, but also about which actions are not worth taking. The explicit acknowledgment of the trade-offs

required to achieve multiple, often competing, goals is an important part of setting priorities.

The proposed Framework consists of three interacting phases:

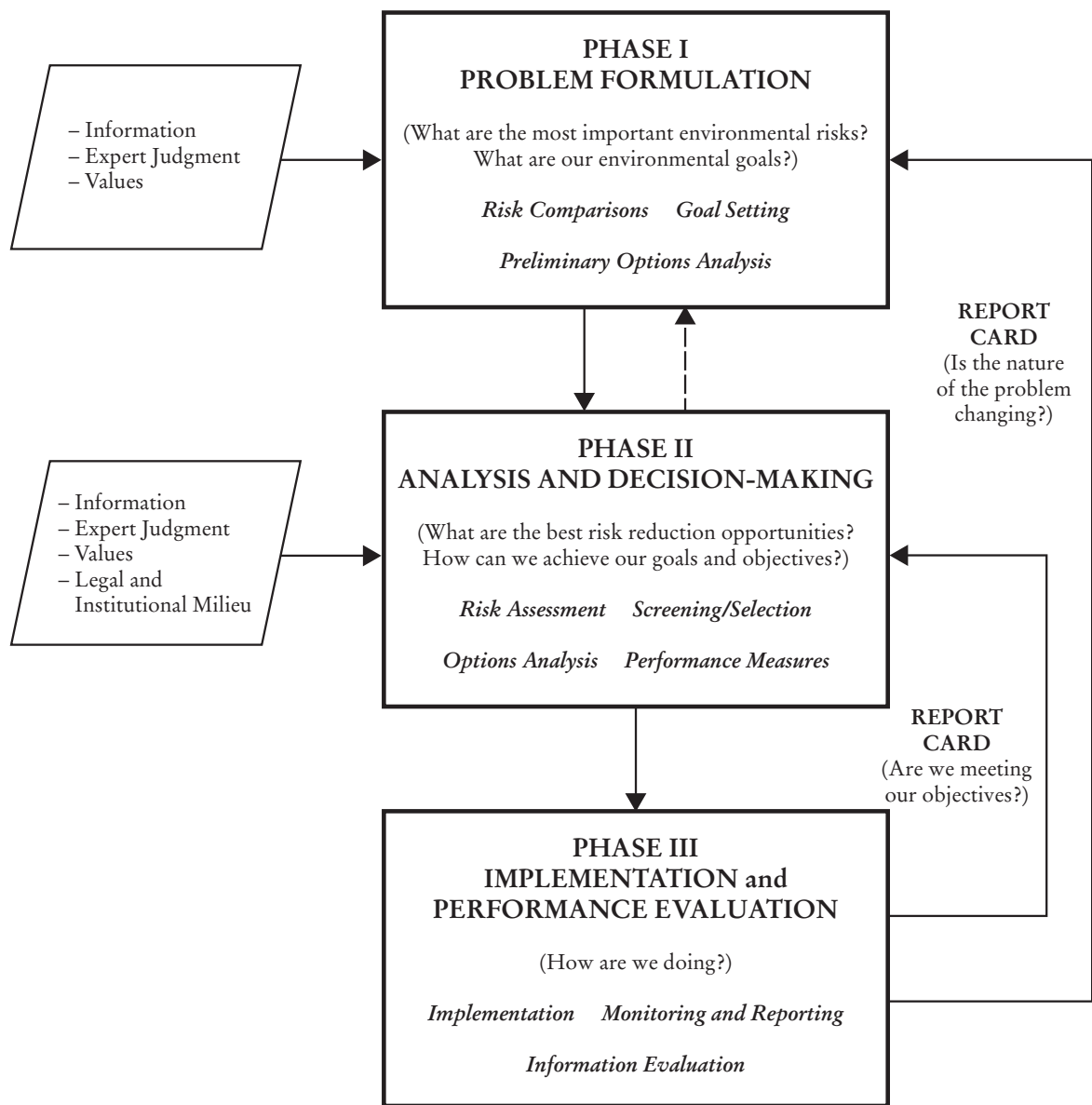
Phase I—Problem Formulation, which involves preliminary analysis and comparison of risks, establishment of goals, and preliminary analysis of risk reduction options. The “problem” may be defined in terms of either a single risk (e.g., one stressor, but associated with multiple sources with multiple routes of exposure) or multiple risks (e.g., environmental stressors associated with a particular geographic location, possibly including multiple sources, pathways, types of receptors, and effects).

Phase II—Analysis and Decision-Making, which includes in-depth analysis of risks and projected risk reduction under possible management scenarios and selection of a preferred option or set of options, based on criteria such as feasibility, cost-effectiveness, seriousness of the risks addressed, and equity.

Phase III—Implementation and Performance Evaluation, in which preferred management options are implemented and the environmental results are monitored and evaluated, thereby providing important feedback so that management approaches can be modified (“adapted”), as necessary.

The various activities that take place during the three phases of decision-making are discussed further below, and in the outputs from the IRP subcommittees.

Figure 1. Framework for Integrated Environmental Decision-making



The straightforward structure of the Framework diagram belies the complexities involved in putting the concept of integrated decision-making into practice. For example, the Framework envisions iterative, analytic/deliberative interactions (NRC, 1996) involving and eliciting values from the Agency, the public, and interested and affected parties. There has been an evolution in the thinking and practice at the

Agency about who should be involved in the assessment and management of risks, with a recognition that public values underlie the selection of specific goals and risk reduction options. Although it is not always clear how best to include a broader range of participants in decision-making, the Agency has begun to implement various aspects of integrated decision-making and is “learning by doing.”

Characteristics of Integrated Environmental Decision-making

Transparency

All parties should be able to follow and understand how the decision was reached.

Flexibility

Integrated decision-making approaches should be applied in a flexible manner depending on the specific circumstance; i.e., where appropriate, to permit valid short-cuts, to eliminate unnecessary procedures, and so to expedite the process of decision-making and implementation.

Dynamic process design

The technical analyses required to implement integrated decision-making should be iterative and interconnected. For example, during the Problem Formulation Phase, problem scoping and definition and preliminary analysis of options will affect the development of goals, and vice versa. Some iteration is also required between Problem Formulation and Analysis, since preliminary analyses will often point out missing elements in the problem definition or inconsistencies in goals.

Explicit feedback, interaction, and cooperation

Integrated decision-making approaches should involve cooperation and open, continuing communication among scientists, managers, members of the public, and others involved in the different phases of the Framework.

The use of information from many sources

Integrated decision-making approaches should draw upon concepts and methods originating in many different scientific, technical, and scholarly fields (e.g., physical and biological sciences, public health, environmental engineering, political science, social science, philosophy, and economics), as appropriate for any given case.

A way of thinking about environmental problems

Integrated environmental decision-making is not just a series of methodologies, but rather is a way of thinking, in a whole and complete way, about any environmental problem in order to maximize the efficient reduction of aggregate risk to populations or ecological systems.

There are also new technical tools available (e.g., improved computer hardware, increasingly powerful computer models, and greater availability of geographic information system (GIS) software) that have improved the Agency's ability to collect, analyze, and disseminate information in ways that will enhance integrated decision-making. In addition, advances in the social sciences are providing improved techniques for helping people develop considered values, for eliciting and using public values in decision-making, for communicating technical information in ways that are helpful to non-expert participants, and for understanding people's choices and preferences.

Although integrated decision-making requires the involvement of a broad spectrum of participants (e.g., scientists, engineers, economists, decision-makers, and the public), the different groups have unique roles to play. In other words, the Framework does not imply that "everyone must be involved in everything all the time." For example, just as scientists are not expected to provide the perspective of the general public, members of the general public are not expected to conduct the technical analyses of scientists. Decision-makers, after considering the various sorts of information (data, views, and judgments) generated in Problem Formulation (Phase I) and Analysis and Decision-making (Phase II), must ultimately make the decision. At the same time, it is important that the various groups maintain effective communication with each other, informing one another of their perspectives and insights, so that the collective wisdom of all of the participants is brought to bear on the problem.

2.2 Problem Formulation (Phase I)

Integrated decision-making should begin with Problem Formulation, in which risk assessors, risk managers, and interested and affected parties seek agreement through extensive dialogue and discussion on what analytical and deliberative steps need

to be taken by whom, by when, and why — if not how. This initial Phase includes three related tasks:

- a) **Risk Comparisons**, in which sets of risks—including risks to ecological systems, human health, and/or quality of life—are ranked or rated, and a set of risks selected for detailed consideration in the second phase;
- b) **Goal Setting**, in which the participants agree on goals relating to the risks of concern and measures that will be used to evaluate progress towards those goals; and
- c) **Preliminary Options Analysis**, in which an initial range of risk reduction options is identified and considered in terms of the estimated total reduction of risk and likely benefit-cost of each.

Risks to Quality of Life

Although "quality of life (QOL) risks" is an imprecise term that means different things to different people, examples of risks often included in this category are aesthetic, economic, and equity impacts, as well as effects on peace of mind, cultural or community identity, and recreational opportunities. In most of the state comparative risk projects, risks to human welfare or quality of life were considered separately from human health and ecological risks by a non-technical subcommittee that developed criteria and produced a ranked list of QOL risks. The EPA (1993) developed a guidebook for assessing quality of life risks that provides a starting point for such assessments.

While scientists can help to characterize risks, they are not uniquely qualified to set priorities among them and broader deliberation is essential.

The dialogue among the participants in Phase I is designed to focus the problem and to ensure that there is a logical consistency between the stressors and risk being considered, on the one hand, and the risk reduction opportunities that may be available, on the other. In this initial Phase, the discussions are at the level of planning, scoping, and screening, rather than the detailed analyses conducted in Phase II.

Scientists play an important role in Phase I by collecting, analyzing, and presenting data in such a way that all parties can appreciate the type and magnitude of the problem(s) under discussion. This activity will generally involve all four parts of risk assessment, including assessment of exposures experienced by special populations and/or ecological resources. Planning, scoping, and screening — including selection of endpoints of concern — also requires explicit input of societal values and stakeholder participation. For instance, while some of the ecological endpoints may be chosen because of their role in a valued ecosystem, there may also be ecological endpoints chosen because of their direct significance to society. Examples of the latter include both economically important species and “charismatic” species. Similarly, in integrated decision-making, judgments may have to be made about diverse health endpoints, such as cancer risks in the general population and the risk of reproductive/developmental risks in children. While scientists can help to characterize such risks, they are not uniquely qualified to set priorities among them and broader deliberation is essential. Finally, decision-makers also play an important role during Problem Formulation; in addition to bringing the scientific and other resources of the Agency to bear on the problem, they also should help to identify the range of potential decisions and viable management options, while examining economic, political, or other constraints on those options. Decision-makers also serve as managers of the overall process.

During the development of the IED framework, the SAB emphasized that, although infor-

mation on the nature and extent of risks is critical to Problem Formulation, the ranking of risk reduction opportunities is equally important when establishing risk priorities. One means of describing the relationship between risk rankings and possible priorities is pictured in Figure 2.

In summary, participants in the initial Phase — scientists, decision-makers, and interested and affected parties — should seek agreement through an open, yet structured, exchange of information, concerns, opinions, and values (i.e., iterative, deliberative-analytic dialogue as described in NRC, 1996) on a series of issues that will define the problem so that more in-depth analyses can be conducted in the subsequent phase of decision-making.

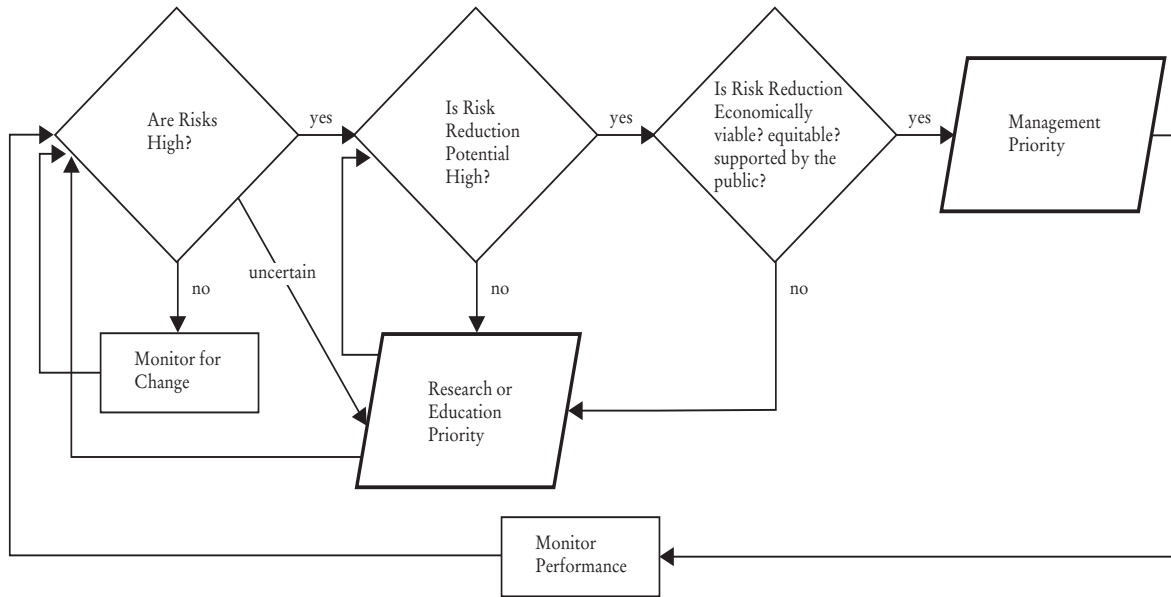
2.3 Analysis and Decision-Making (Phase II)

In Phase II of the IED Framework, the analysts take the information and general directions gained in Phase I and generate more detailed, more fully supported assessments of risks and risk reduction options. For integrated decision-making, options analysis should include consideration of risk reduction opportunities with regard to their technical feasibility, aggregate risk reduction to be obtained (e.g., reductions in “target” risks and collateral reduction in all affected risks), full economic consequences of various risk reduction scenarios, and so forth. Decision-makers also should request analysis of potential options with regard to sustainability, equity, and other potential decision criteria.

Options analysis generally is more “analytic” than “deliberative” (NRC, 1996) although a continued level of interaction between the participants in the overall process (scientists, risk managers, and interested and affected parties) is important. Options Analysis is also more resource-intensive than Problem Formulation.

In the decision-making portion of Phase II, the

Figure 2. The Relationship Between Risk Rankings and Possible Priorities



Agency or other decision-makers should a) utilize outputs from the analyses of risk and risk reduction options, b) consider widely-held public values, as well as the views of participating stakeholders, c) consider the legal, economic, and institutional constraints, and d) ultimately, make the decision. Clearly, this process is not totally scientific. However, the best science should inform and contribute to decision-making. Developments in the social and decision sciences, for example, are providing improved methods for value elicitation and multi-attribute decision-making. The documentation supporting the decision should make explicit a) the implications of the chosen management option(s) to the health of ecological or human systems, b) the economic costs and benefits associated with the selected option, and c) the societal values that both influence and are affected by the decision, including values relating to

economic efficiency, sustainability, equity, and quality of life. Integrated decision-making requires explicit consideration of the trade-offs involved in pursuing multiple environmental goals and/or in simultaneously pursuing environmental and non-environmental goals. In some cases, analysis may indicate that a particular management option is not worth doing because of the greater good that might be achieved by investing those resources toward the achievement of another goal.

It is important that the scientific and technical analyses prepared during Phase II articulate clearly the uncertainties associated with the estimates of risk, the estimates of risk reduction that may be achieved by different management options, and the economic assessments of various risk management scenarios. Integrated decision-making does not eliminate the uncertainties associated with making decisions. However, by encouraging an

Integrated decision-making requires explicit consideration of the trade-offs involved in pursuing multiple goals...

*The SAB
advocates the
use of
Environmental
Report Cards
to document
performance
and outcomes
of risk
reduction
activities...*

open and comprehensive examination of environmental problems, integrated decision-making should lead to a clearer identification of the nature, extent, and consequences of the uncertainties associated with the available information. In any event, environmental decision-making must proceed in the presence of uncertainties, and nothing in the proposed Framework should be construed as precluding environmental decisions simply because uncertainties remain.

2.4 Implementation and Performance Evaluation (Phase III)

In the third phase of integrated decision-making, the chosen risk reduction option or set of options is implemented and evaluated over time to ascertain the extent to which it is achieving the desired environmental outcomes. The specific activities required to implement an environmental decision

will depend on the suite of management options selected for any particular problem or set of problems. The Agency has considerable experience with many risk reduction options (e.g., adopting best available technology, imposing permit limits, and regulatory negotiation), and is gaining valuable new experiences with others (e.g., National Environmental Performance Partnership System).

In contrast to implementation, the performance evaluation process is fundamentally rooted in science because it is science that can translate the public's overarching environmental goals (e.g., improved health, sustainable ecosystems) into discrete, measurable components. Accordingly, science is essential in deciding what to monitor, i.e., specifying the endpoints of concern for the systems at risk and identifying the specific measures that need to be monitored in order to characterize the status and trends for those endpoints with respect to the environmental goals. Further,

Desired Outputs from Problem Formulation:

The initial goals for the decision-making exercise, including environmental goals to be achieved;

Which environmental problems/stressors/systems will be included and which will not, and the reasons for these decisions;

The health, ecological, and quality-of-life effects of concern;

The spatial, temporal, and organizational dimensions of the problem;

Relevant data and models, and possible approaches to data analysis;

Scoping of the uncertainties involved and research needed to significantly reduce critical uncertainties;

Initial review of the range of options available to reduce risks, considering likely economic, political, or other constraints;

The endpoints upon which the condition of the ecological, human health, or societal systems ultimately will be judged; and

The types of factors that will be considered when reaching a decision.

issues such as spatial and temporal variability, measurement error, and time lags must be addressed explicitly in order to demonstrate environmental conditions and to separate signal from noise. And finally, reference conditions and benchmarks or milestones along the way to the desired system conditions must be defined scientifically so that meaningful and measurable performance criteria for success or failure can be defined.

The SAB advocates the use of Environmental Report Cards to document performance and outcomes of risk reduction activities at several levels and for different audiences. As noted in Figure 1, a successfully implemented performance evaluation system will generate several important feedbacks affecting the first and second phases. One feedback loop is to the Analysis and Decision-Making Phase, reporting on how well the selected risk reduction options and strategies are achieving the environmental goals. This feedback loop allows for adaptive management and changes in implementation activities, including the possible need to identify and analyze additional options to further reduce risks. Information also feeds back into Phase I allowing re-examination, as needed, of the initial goals, risk rankings or other aspects of Problem Formulation. As risk reduction options are put into place, for example, particular risks should be reduced, and a new comparison of risks may be appropriate. In addition, there may be a shift in or redefinition of societal values over time, requiring different sets of environmental goals and, therefore, different environmental decisions. In short, integrated decision-making emphasizes the need for performance information at several points in the process and for systematic review of environmental decisions in light of new scientific understanding, shifts in societal values, changes in stakeholder preferences and available resources, and/or responses of the environment to previous decisions.

2.5 Building on Previous Frameworks

The IED Framework builds upon several previous efforts, in particular the risk assessment/risk management model described by the National Research Council (NRC, 1983), the update to that report (NRC, 1994), the ecological risk assessment framework (U.S. EPA, 1992), the report of the Presidential/Congressional Commission on Risk Assessment/Risk Management (1997), and the risk characterization process described by the NRC (1996), which focused on the interaction between analytic and deliberative processes in decision-making.

Building on this base of information, the IED Framework is intended to integrate a range of factors that are important in modern risk assessment and risk management (see box). In particular, the process envisioned in the Framework moves beyond these earlier efforts in the three areas discussed below.

2.5.1 Integrated Aspects of Single Stressors/Risks

Although the SAB emphasizes that the Agency should consider multiple stressors in an integrated manner, it recognizes that integrated thinking also can enhance the decision-making process for single stressors, which have typified many Agency decisions in the past. When a single stressor is considered, integrated thinking should expand the previous approaches by:

- a) Characterizing stress-effects relationships across all systems and populations;
- b) Exploring a broader range of risk reduction options, some of which may be qualitatively new;
- c) Assessing the benefits and costs of each option, including explicit consideration of non-monetary benefits and costs;

- d) Assessing the magnitude and nature of the aggregate risk reduction associated with each option;
- e) Involving scientists, options analysts, stakeholders, and risk managers collectively at various points throughout the process; and
- f) Establishing a performance evaluation “report card” to characterize the efficacy of the implemented risk reduction option and to signal both the need and opportunity for adapting the original management decision.

2.5.2 Integrated Aspects of Multiple Stressors/Risks

One of the most important extensions of integrated decision-making is its focus on multiple stressors. The SAB suggests prototypic structured approaches that can be used to begin to explore multiple ecological risks and multiple human health risks. In some cases these approaches will lead to consideration of combinations or groups of stressors; e.g., all organophosphate pesticides, all automobile emissions, or all factors leading to local loss of biodiversity.

Types of Integration in the IED Framework

Risk Comparisons

Consider a wide range of environmental risks simultaneously so that the seriousness of risks can be characterized relative to one another.

Integrated Risk Assessment

Develop scientific data and analytical methods for assessing risks from multiple stressors, from multiple sources, by multiple exposures, resulting in multiple effects/outcomes, in order to represent real world situations more accurately.

Integrated Analysis of Management Options

Investigate options to reduce subsets of ranked risks, rather than considering single risks in isolation, in order to achieve greater aggregate risk reduction.

Integrated Analysis of Economic Consequences

Identify the full range of benefits and costs, both monetized and non-monetized, associated with reduction of multiple risks.

Integrated Performance Information

Use performance evaluation measures to better characterize conditions and to adapt implemented actions appropriately.

Integrating Multiple Disciplines and Points of View

Understand and utilize information from all concerned parties in decision-making.

Initial steps in integrated decision-making should produce relative rankings of risks to human health and ecosystems, independently. In the context of integrated decision-making, however, it is also important to go further and develop integrated health and ecological risk rankings. A merger of such qualitatively different risks into a single scheme requires even larger value judgments than the ranking of similar risks and should be informed by a broader societal valuation process.

Qualitative differences in human health and ecological risks should be considered during Problem Formulation. For example, the focus of health and ecological risk assessment is different; that is, the focus of health risk assessment is an individual within a single species, while the majority of ecological risk assessments focus on entire populations of one or many species. More generally, ecological risk assessments often address the integrated risks to a prescribed region, such as a watershed, versus health risk assessments that are generally more national in scope. This difference is reflected in the different types of stressors of concern; cf., carcinogens for humans vs. habitat fragmentation. However, in those instances in which there are common stressors of concern (e.g., chlorinated pesticides or climate change) or where effects of a stressor on an ecological system produce effects on human health or quality of life (e.g., habitat alteration that affects the range and activity of disease vectors and infective parasites, or changes in the abundance of commercially important or endangered species), there is an opportunity for some merging of concerns to take place. Integrated decision-making should combine risks into logical groupings, e.g., those with a common source or pathway, in order to identify risk reduction opportunities across stressors. In order to be successful, this analysis requires open, publicly-accessible, and frequent dialogue among those who assess and compare risks, those who determine methods for reducing risks, and those

who make the final decisions. In summary, as integrated thinking is developed to address multiple stressors, it should:

- a) Lead to a more realistic comparison of risks to humans and to ecosystems, where some of those risks may be posed by combinations of related stressors;
- b) Lead the Agency to consider in a systematic fashion all of the appropriate factors related to risks in a given circumstance, including aggregate risk, economic factors, and societal values; and
- c) Lead to action that will increase the reduction in aggregate risk posed by a combination of stressors in a given circumstance.

2.5.3 Considering Environmental Values

The SAB's integrated environmental decision-making Framework highlights the analytic/deliberative process (NRC,1996). It is through such a process that societal values intersect with the scientific risk characterization and risk reduction analyses. The integrated decision-making concept emphasizes the role and timing of stakeholder and decision-maker inputs to the analytic processes. It explores more deeply the valuation of environmental outcomes and risks and the need to include not only the concepts of economic efficiency and willingness-to-pay, but also issues such as environmental sustainability and equity. Societal values constitute the milieu in which integrated environmental decision-making occurs, forming the basis of goals for improved social welfare, improved ecological/health conditions, and long-term sustainability and equity. Ultimately, it is in the realm of social values that the success or failure of environmental decisions will be judged.

Integrated decision-making should combine risks into logical groupings, e.g., those with a common source or pathway, in order to identify risk reduction opportunities across stressors.

3. WORKING TOWARD IMPLEMENTATION

The elements within the Phases of the Framework and how they interact with each other are at the heart of an integrated approach to decision-making. This section of the report elaborates upon many of those elements and points the way for further development of each in order to meet the needs of integrated decision-making.

3.1 Comparative Risk for Problem Formulation (Phase I)

The term Risk Comparisons is used in this report to denote the characterization and ranking of risks posed by environmental stressors, where an environmental stressor is any physical, chemical, or biological change or agent that could affect ecological or human health systems. The objective of risk comparisons is to determine how members of an array of risks compare in magnitude and scope to each other, so that a subset of risks can be identified for simultaneous evaluation and decision-making. As depicted in the Framework, the resulting information on comparative risk should be integrated with other relevant technical information (including expected costs and benefits), expert judgment, and values brought into the process through deliberation with interested and affected parties. This interaction in Phase I should lead to agreement on goals, limitations on analysis, and a tentative identification of possible risk reduction options.

3.1.1 What We Have

One approach to Risk Comparisons, developed by the Ecological Risks Subcommittee (ERS)

and applied to the comparison of ecological risks, utilizes an expert group to develop and weight risk ranking factors in order to produce the group's consensus judgment of the relative risks associated with various environmental stressors. The ERS approach considers the two fundamental components of ecological risk—the stress or exposure regime and the response or ecological effects regime—for each stressor of concern. Because each stressor may result in multiple effects on different entities in an ecosystem, the goal of the risk comparisons is to characterize the dominant relationships between the environmental stressors and ecological effects. Ecosystem-specific stress-effect relationships are then transformed into a relative ranking of risk at a specific spatial scale (e.g., regional, national, or global) by applying a series of numerical factors that, in the Subcommittee's view, reflect the relative impact of the effects on the ecosystem(s) at risk.

The ERS categorized ecological risks from chemical, biological, and physical stressors into five narrative categories: Highest, High, Medium, and Low Ecological Risks, and Unknown But Potentially Important Risks. Stressors ranked by the ERS as posing Very High ecological risks are listed in Table 1. These conclusions represent the consensus expert judgment of the Subcommittee, based on general ecological principles. The transparency of the ERS methodology allows others to evaluate the scientific bases for the risk rankings and to reach their own conclusions. A different group of experts, using a different set of risk factors or weightings, might come to different risk rankings. Nevertheless, the conclusions of the

The SAB suggests prototypic structured approaches for rating multiple ecological risks or multiple human health risks.

Table 1. Environmental Stressors Posing the Highest Risk at the National Scale: Conclusions of the ERS*

Hydrologic Alterations
Harvesting Living Marine Resources
Habitat Conversion
Climate Change
Introduction of Exotic Species

*Given current efforts to manage risks

ERS are consistent with other previous national rankings of ecological risks (e.g., EPA, 1987; SAB, 1990) and suggest that the present greatest risks to the nation’s environment result from physical and biological, rather than chemical, stressors. Further detail on the ERS method and findings will be provided in a separate SAB report.

A second approach to Risk Comparisons, less fully developed by the Human Exposure and Health Subcommittee (HEHS) and illustrated using human health risk issues, employs Internet-based polling of individuals (experts) for their (professional) judgment of the relative degree of risk associated with various stressors, and solicits information on which factors most influenced this judgment and the degree of confidence each individual (expert) assigns to his/her assessments (see Figure 3). Thus, this method for developing risk comparisons also provides information on the range of recorded opinions.

The HEHS developed a prototype for an Internet-based system for polling and characterizing expert judgments about the risks posed by various environmental stressors. The prototype restricted-access Internet site includes an Entry Page, where survey participants register, followed

by a Ranking Page (Figure 3), where participants are asked to rate a series of stressors as Very High, High, Medium, Low, Very Low, or Unknown Risk. The Ranking Page also asks for the factors that influenced the rating and a confidence rating for each risk ranking. The Ranking Page contains an Information Window, which allows participants to access summary information for each stressor. The HEHS recommends that information be provided on relevant exposure routes and pathways, population exposed, average dose, toxicological and health effects data, and so forth. An example of the output data that would result from the polling approach is shown in Figure 4.

While there were some differences, the two subcommittees proposed quite similar sets of factors that they felt were important in evaluating the comparative risks associated with various environmental stressors (see box). Both subcommittees also recommended that information on each of the factors be assembled in a summary format—a risk data sheet—to assist non-expert participants in Problem Formulation to assess the relative priority that should be accorded each stressor.

The consensus approach or the individual polling approach could be applied to either human health or ecological risk comparisons using stressors and rating factors specific to each group. The methodologies also could be used to elicit stakeholder or public views on risk priorities by expanding the composition of the surveyed or empaneled group. Clearly, there will be variation among the results of the various groups — even among groups of experts — because of differences in level of expertise and knowledge about a particular stressor or because of differences in the degree of concern that individual participants attach to various health or environmental outcomes associated with a stressor.

While the examples developed by the ERS and the HEHS provide illustrations of the type of new tools we believe need to be developed, these

Figure 3. Internet-based risk rating form. The respondent selects a stressor, then accesses the data sheet by selecting the Information Window.

Stressor Risk Characterization and Health Risk Ranking Data Sheet
 Edit/Update Risk Data

For
 Dr. Bernard Weiss
 Univ. of Rochester
 weiss@envmed.rochester.edu

If the above information is **NOT** correct for **YOU** return to the [Login page](#) and enter **YOUR** name and **PASSWORD**.

Review or Update your current entry on Stressor: Halogenated Hydrocarbons

Get INFORMATION ON: Halogenated Hydrocarbons	Relative Risk Rank	Confidence in Ranking	Factors influencing ranking Check all that Apply
Open Information Window Please rank stressor and indicate your confidence in your ranking: Review of General Instructions Last Updated 11-Dec-1997 9:54:16AM	<input type="radio"/> VH <input type="radio"/> H <input type="radio"/> M <input type="radio"/> L <input type="radio"/> VL <input type="radio"/> ?	<input type="radio"/> VH <input type="radio"/> H <input type="radio"/> M <input type="radio"/> L <input type="radio"/> VL <input type="radio"/> ?	<input type="checkbox"/> Size of population affected <input type="checkbox"/> Particular subpopulations <input type="checkbox"/> Severity of health effects <input type="checkbox"/> Percent of attributable incidence <input type="checkbox"/> Persistence in the environment <input type="checkbox"/> Potential future risk

Other reasons for ranking:

specific examples were created with limited consideration of the literature in modern social and decision science. As the Agency develops and refines such tools for future use, it will be important to involve experts from these fields.

3.1.2 What We Need

During the design of the Framework, the SAB participants acknowledged that technical risk rankings, in isolation, offered insufficient guidance for policy decisions. Given the multitude of prob-

lems and issues to be addressed, a more comprehensive and systematic framework for analyzing and reducing environmental health, ecological, and quality of life risks appeared necessary. During Problem Formulation, the Agency needs methods for comparing risks that are robust, transparent, effective, and inexpensive. As noted, some initial steps have been taken for ranking risks within categories; e.g., human health, quality of life, or ecosystem risks.

Additional work, however, needs to be done on methods to incorporate non-expert values in

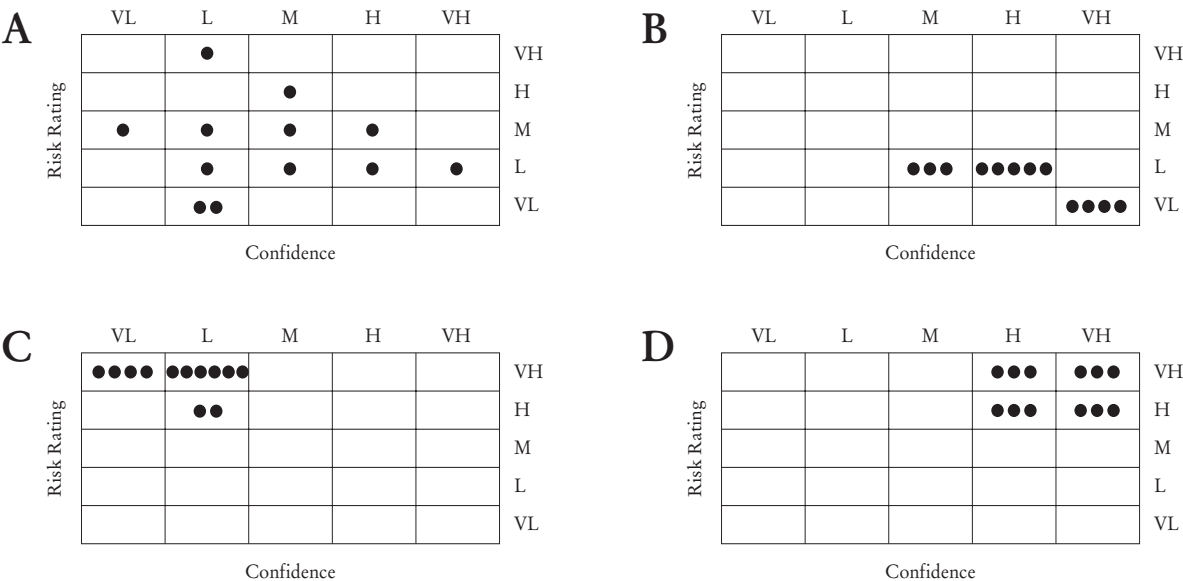
risk comparisons and priority-setting, including inputs from the general public as well as interested and affected parties, and to integrate the analysis of multiple risks.

The assessment and comparison of risks and the definition of environmental goals are inter-related. In other words, scientific information on the nature and extent of various risks influences the relative priority that society places on those risks. In addition, other factors (e.g., dread, previous experiences, the degree to which exposure is voluntary, and underlying values) also influence the relative priority assigned by the public to environmental risks. For this reason, the ultimate priorities for action that emerge during Problem Formulation should be a product of the interaction between risk comparisons by experts and the more inclusive goal-setting processes, supple-

mented by a preliminary assessment of risk reduction potential of the various options. The purpose of ranking risks and ranking risk reduction opportunities is to assist decision-makers to allocate resources in Phase II.

The interaction between risk comparisons and goal-setting could be enhanced if the risk comparisons are structured so as to identify linkages between health, ecological, and quality of life risks; e.g., common stressors or root causes, indirect affects on health of an ecological impact. Defining risk problems using a common dimension (e.g., in terms of stressors) will facilitate the identification of both direct and indirect effects of stressors, and of those stressors that affect both humans and natural systems. Approaches for achieving this sort of integrated analysis will require further development.

Figure 4. Synthetic plots of risk versus confidence (12 respondents): A) high variability; B) low risk, mid to high confidence; C) high risk, low confidence; D) high risk, high confidence.



3.2 Risk Assessment for Analysis and Decision-Making (Phase II)

3.2.1 What We Have

The Agency has been a leader in developing guidelines for risk assessment. Beginning with the first version of cancer risk assessment guidelines in 1976, the Agency now has risk assessment guidelines in place for six human health endpoints. In addition, the Agency broke new ground with the publication of ecological risk assessment guidelines in 1998. These guidance documents — and their updates — provide state-of-the-art information on how to perform detailed analytical assessments of risk that can inform the decision-making process.

In 1997, the Administrator signed a Cumulative Risk Policy that committed the Agency to move in the direction of assessing the multiple effects of multiple stressors through multiple routes of exposure, which is certainly

consistent with the Framework. This Policy, however, promises a level of sophistication in risk analysis that currently does not exist.

3.2.2 What We Need

Most of the risk assessment guidelines that are in place generally address single stressors resulting in single endpoints; e.g., the cancer risk from arsenic. However, the public is increasingly asking more holistic questions; e.g., “What is my total risk of living in this environment?” Implicit in the question is consideration of the total risks from varying, complex mixtures of stressors, as well as the cumulative impacts of multiple exposures, experienced over time and space, to populations who might have differing degrees of susceptibility and resources to address the consequences of those risks. In addition, current guidelines imply that the goal of reducing risk to a specified level (e.g., 10^{-4} or 10^{-6} lifetime cancer risk) is to be pursued regardless of the associated benefits and

Correspondence of Human Health and Ecological Risk Comparison Factors

Human Health Risk Factors

Size of population affected
Particular subpopulations at risk
Severity and persistence of effects
Persistence in environment and/or human body
Percent of attributable incidence
Potential future risk

Ecological Risk Factors

Proportion of resource at risk
Distribution of “hot spots”
Recovery potential, species depletion
Duration of stress-effects co-occurrence

Secondary stress induction
Special ecological significance

costs, including opportunity costs. When benefit-cost and other information is considered, however, the public may set a different priority among multiple public welfare goals. The scientific community has taken the initial steps in scientific risk assessment by applying simplifying assumptions; cf., a generic receptor exposed to a single stressor under one set of conditions. This is analogous to the first approximation methods used in the physical sciences, such as assuming no atmosphere in gravity experiments. But now the scientists appear to be more willing — even insistent — to ask the more “real world” questions associated with complex mixtures and diverse populations. However, the need for such information and the willingness to work on the problem have yet to yield suitable and effective methods. Much work remains to be done and much experience is yet to be gained before we will be able to assess cumulative risks posed by multiple stressors and/or multiple exposures over time.

3.3 The Analysis of Benefits and Costs in Decision-making (Phases I and II)

In deciding what to do about a particular environmental problem, it is impossible to escape the question of values. At its heart environmental decision-making is about how people, acting as individuals or through their government, can make themselves best off through actions that affect the environment directly and indirectly. Judging which choice, among alternative actions, will produce the most “well being” requires information not only on risks, but also on how “well being” (i.e., goals and the relationships among goals and among alternative choices or actions) is defined. Integrated decisions on whether and how to address certain environmental risks or sets of risks requires the consideration of both a full range of risks and the full economic consequences associated with possible decisions. An understanding of the tradeoffs implied by these choices is crucial both when

problems are formulated for consideration (in Phase I) and when they are being analyzed in detail to support decision-making (in Phase II).

3.3.1 What We Have

The work of the Economic Analysis Subcommittee (EAS) is presented in a separate SAB document that describes the strengths and limitations of benefit-cost analysis. In short, risk information, by itself, is inadequate to guide decisions because there are a near-infinite number of substances and conditions that can impose harm, and it is impossible to act to eliminate them all. The ability to reduce risks is limited by the resources of labor, capital, knowledge (technology), and physical endowment available to devote to the task. The task of environmental decision-makers is to provide — for now and for the future — the healthiest, safest, most ecologically secure set of conditions for which the American people are willing to pay, in the face of other competing goals. Given these conditions, the decision-maker can use a number of approaches (within the limits of enabling legislation) to determine whether and by how much to reduce risk. Prominent among these approaches is benefit-cost analysis that seeks to strike a balance between the benefits associated with reducing risks and the costs associated with taking a particular action. In ideal terms, benefit-cost analysis measures the good and bad effects of a proposed action in some common term so that decision-makers can more directly determine whether the associated gains to society will outweigh the losses.

In real terms, the application of benefit-cost analysis to environmental decision-making is challenging. On the one hand, assessing benefit is difficult. Often the goods and services that come from ecosystems are not traded in markets. Further, even if real markets exist for the goods and services, the changes in human health and ecosystem functions associated with a particular action are difficult to predict or measure. Where

The task of environmental decision-makers is to provide — for now and for the future — the healthiest, safest, most ecologically secure set of conditions for which the American people are willing to pay...

markets exist, economists have well-established methods for determining peoples' willingness to trade one resource use for another. Where markets do not exist, however, economists must use techniques that are more controversial in order to estimate the values people place on an ecosystem good or service.

Cost is also difficult to assess, especially when viewed as economists do as opportunity costs, government administration costs, transaction costs, general equilibrium effects, and social impacts, in addition to direct compliance costs. (Opportunity costs are the foregone social benefits associated with applying scarce resources to environmental protection instead of other possible uses of those resources.)

Other challenges for the benefit-cost analyst include consideration of time and equity. Costs and benefits associated with an action may not be realized over the same time period (e.g., benefits may accrue to present generations, but costs to a future generation, or vice versa). This difference in the time horizon often raises equity concerns. In addition, future costs and benefits cannot be compared directly with current costs and benefits without taking into account the potential earnings that may be associated with deferred expenditures and consumer preferences for consumption in the present vs. in the future. Thus, economists have developed a system of discounting the stream of benefits and costs as they are realized over time so that future costs and benefits can be compared with present costs and benefits. Although the discounting process can be controversial, many economists believe that discounting of the streams of benefits and costs in a consistent way is essential to show current decision-makers the full implications (present and future) of alternative choices.

In the matter of equity, while benefit-cost analysis generally provides a societal level view of the benefits and costs associated with a proposed action, the technique is less adept at accounting for the uneven distribution of those benefits and costs

across different individuals and groups in society. Another complicating factor is that individuals affected by the environmental action are often unequally endowed in wealth and income. This difference influences both the benefits and costs as they enter the evaluation framework, and the sense of fairness that pervades the results. Although benefit-cost analysis can shed light on these distributional issues, such analysis cannot answer the societal question regarding the desired distribution of benefits and costs. The definition of what is "equitable" is left to the decision-maker, in conjunction with the other participants in the decision process.

3.3.2 What We Need

As noted above, more work needs to be done to enable decision-makers to assess the impact of potential decisions on the distribution of benefits and costs across the population and on society at different points in the future. In addition, the Framework suggests a role for benefit-cost analyses on the impacts of potential management options to help formulate risk reduction priorities. "Rough-cut" benefit-cost analyses should be sufficient as first approximations of whether the options are economically feasible or not.

In summary, benefit-cost analysis is a consistent, coherent, and transparent tool for looking at trade-offs among competing goals. When well done, the products of specific benefit-cost analyses can generally be relied upon as useful inputs for decision-making purposes, but are always limited by data and sometimes by methodology. In some cases and for some questions (e.g., equity), the inherent uncertainties limit benefit-cost analysis to providing only indicative information, which, nonetheless, can be useful. As with risk assessment, risk comparison, and other elements in the Framework, there is a recognition that even the best and most complete benefit-cost analysis is inadequate, by itself, to yield "the answer" in a

particular case. Additional work is needed to refine existing approaches for forming and eliciting the values that individuals place on possible environmental or health outcomes and on their preferences among possible risk reduction options. The use of deliberation, as part of or as a complement to more traditional benefit-cost analyses, holds promise for characterizing difficult-to-monetize values and thus bringing those values to the table. The next section discusses these issues in greater detail.

3.4 Forming, Eliciting, and Considering Public Values (Phases I and II)

The term “values” takes on two meanings in integrated decision-making, and it is important to distinguish between the two in order to avoid confusion and mis-communication. In the first instance, “values” refers to the set of underlying factors that, taken together, cause people to hold the opinions that they hold and to make the choices that they make when presented with real situations. There are many such value systems that contribute to the normative makeup of people in a diverse society. The diverse nature of peoples’ values contributes to the complexity and difficulty responsible authorities face when making decisions on whether or not to act to reduce risks. These values must be considered, along with the statutory framework and other factors, when goals are identified during Problem Formulation.

In the second instance, “values” is used in an operational sense as a measure of what one outcome is worth in comparison with alternative outcomes. This is the sense in which values are reflected in benefit-cost analysis and is the sense in which the term is used in this section.

3.4.1 What We Have

The Valuation Subcommittee (VS) engaged in a series of intensive discussions that explored the nature of natural resource valuation and the basis behind the public construct of values. The general

themes that emerged during the Subcommittee’s discussions are listed in the box on page 26.

The VS discussions affirmed the notion that integrated environmental decision-making requires a process within which the decision-maker can meld the results of science and the goals of the people served and formulate acceptable decisions. In principle, economic analysis provides one such approach to valuing the human health and ecosystem benefits of proposed actions in terms of the change in economic well-being associated with the action. Economic values from this approach are said to be derived from the vector of all underlying abstract values held by individuals in concert when a situation is presented.

By their nature, changes in human health and ecological conditions often are not easily observed in quantifiable terms that can be rendered in the monetary units that most often are used to compare possible outcomes in benefit-cost analyses. For this reason, some people assert that the benefits received from environmental protection are systematically under-estimated and, consequently, that ecological systems and human health are under-protected as compared to other goals and desires of people.

An example of the difficulty faced by decision-makers can be seen in the case of determining ecosystem values. In principle ecosystem values are not different from other values, and they need not enter into the decision process in any unique way. At the same time, however, measuring and incorporating the values ascribed to anthropogenic changes in ecological conditions does present serious difficulties that require special care.¹²

Ecosystem value can come from direct use, from indirect use, or simply from the value that the public places on keeping the ecosystem viable

...integrated environmental decision-making requires a process within which the decision-maker can meld the results of science and the goals of the people served...

¹² Although the VS focused on ecosystem valuation, valuation of human health conditions presents similar challenges in environmental decision-making.

Deliberative processes play an important role in eliciting values of people, and in obtaining stakeholder participation in decision-making.

(“existence value”). Eliciting these values is difficult for several reasons. For example, people doing the valuing often have insufficient knowledge of how changes in ecological factors affect the things they care about. They need expert scientific assistance in making the important connections. Also, many of the benefits from ecological systems are subtle and do not enter into conscious consideration in the normal course of events, in contrast to market goods and services which are much more evident. To account for these benefits, special techniques for eliciting preferences are required. In addition, some of the values ascribed to ecological outcomes (e.g., equity, sustainability, and stewardship) arise in a social context and may not surface from commonly used individual preference measures.

Most importantly, because ecological services often do not enter into markets or enter them incompletely, it is difficult — if not impossible — to provide robust and dependable monetized measures of the benefits they deliver. Often it is

not possible to even determine quantitative measures for differences in outcomes. Qualitative measures of benefits and costs, therefore, must be arrived at and then incorporated into decision processes. In short, the valuation of ecological costs and benefits is prone to error because elements valued by people may be omitted or incorrectly specified and because measurement is inherently more difficult than with goods and services for which market and market-like measures are available.

Because of these limitations, there is a need to improve existing methods for estimating the value that society places on various aspects of human health and ecological condition. One approach to assure that all relevant elements are included in decisions, and that they are valued properly, is to expand the use of deliberative processes. Deliberative processes play an important role in eliciting values of people, and in obtaining stakeholder participation in decision-making. If such

Environmental Valuation Themes

Ecological valuation is an anthropocentric exercise; i.e., people’s wishes count; there is no external set of values waiting to be discovered for application to decision-making.

The value of anything reflects its contribution toward the achievement of some goal. The process of valuation cannot be separated from the need to reach agreement on goals.

Environmental valuation requires interaction and deliberation among scientists, decision-makers, and other stakeholders to identify goals and to define endpoints to characterize those goals.

Existing economic approaches, broadly considered, are consistent and coherent frameworks for valuation because they organize a system of trade-offs. However, they are not mechanisms for producing “the answer” because they may omit trans-economic values that may be important, may include some elements that are difficult or impossible to estimate, and may employ preference elicitation processes that are incomplete.

An expanded, rich, and complex process using multiple approaches is required to fully encompass ecological valuation.

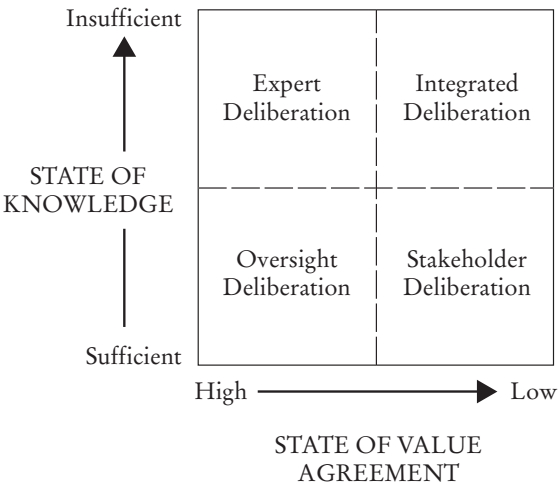
processes are used discriminately and tailored to the situation, they should lead not only to more satisfactory results, but also should not delay — and indeed may even speed the delivery of— environmental protection because they lessen post-decision controversy.

However, incorporating people’s values and preferences into decision-making is not an easy task. For instance, not all values, and therefore the preferences they reflect and the choices they direct, are equal within or across people. Some values are held more tightly than others, and thus would be expected to be traded-off differently — if at all — from those of lesser importance to individuals. Further, stated preferences may be constructed during the elicitation process itself. Knowledge of decision theory, cognitive processes, and how people react to complex situations in reaching decisions can help inform deliberative processes that are intended not only to elicit values information but also to obtain stakeholder participation in the decision-making process. Finally, the deliberative processes must be open and transparent so that people can understand how decisions are made. Through such openness and the use of procedures that are common to facilitation and mediation, institutions can build trust and thereby help to legitimize the processes used in integrated decision-making.

The VS identified four classes of decisions and the type of deliberative process that would be appropriate for each (Figure 5).

When agreement about values (economic and non-economic) is high and the state of knowledge (relevant science, economics, and social science) is sufficient and/or non-controversial, Agency decision-making is likely to be routine and deliberation will only be needed periodically, if at all, for oversight (**oversight deliberation**). At the other extreme, when agreement about values is low and the state of knowledge is insufficient and/or controversial, decision-making is likely to require multi-dimensional tradeoffs based on insufficient

Figure 5. Typology of Deliberation Processes with Stakeholders and Experts (adapted from Chess et al., 1998)



knowledge. In this situation, **integrated deliberation**, involving both experts and outside stakeholders, is needed throughout the decision-making process. Between these two extremes lie intermediate intensities of deliberation to fit intermediate states of knowledge and agreement on underlying values.

3.4.2 What We Need

The Working Paper that resulted from the VS effort offers recommendations for a future workshop to explore the topic of natural resource valuation more fully with a larger group of participants, including interested and affected parties. The SAB experience testifies to both the importance and the difficulty of such open discussion, frank exchange of views, and search for common ground. A workshop that reaches out to a larger audience could be beneficial. While it is not certain

that such a workshop will settle the remaining questions regarding natural resource valuation, such a workshop should further the Agency's understanding of recent valuation developments, additional methods for eliciting public values, and the role of valuation in integrated environmental decision-making.

In addition, there is a need for further research on and experimentation with approaches to valuing benefits of environmental systems. Existing approaches are inadequate in their treatment of such values as fairness and sustainability. They also have difficulty in incorporating the systemic benefits of ecosystem attributes such as biodiversity and are incomplete in their treatment of dynamic responses of ecosystems to change. More holistic approaches that take into account the web of interactions among decisions surrounding ecological systems and related production and consumption activities would be helpful.

3.5 Options Analysis (Phases I and II)

In both Phase I and Phase II, after iteratively assessing and comparing environmental risks and considering the implications of various risk reduction possibilities on the grounds of economics or other measures of welfare, the IED Framework calls for an overall design and selection of risk management scenarios to address the environmental problem at hand. Such Options Analysis during Problem Formulation (Phase I) informs goal-setting, thereby ensuring that goals are not defined solely on the basis of risk, but also take into account possibilities to reduce risks within likely constraints and trade-offs that will be required among goals. During Phase II, when the environmental problem(s) and associated environmental goals have been defined, Options Analysis becomes a more in-depth consideration of possible risk reduction options. In both Phases, the possible options should be analyzed with regard to their potential to reduce single and

multiple risks of concern, associated costs, sustainability, equity, and other criteria specified by the participants.

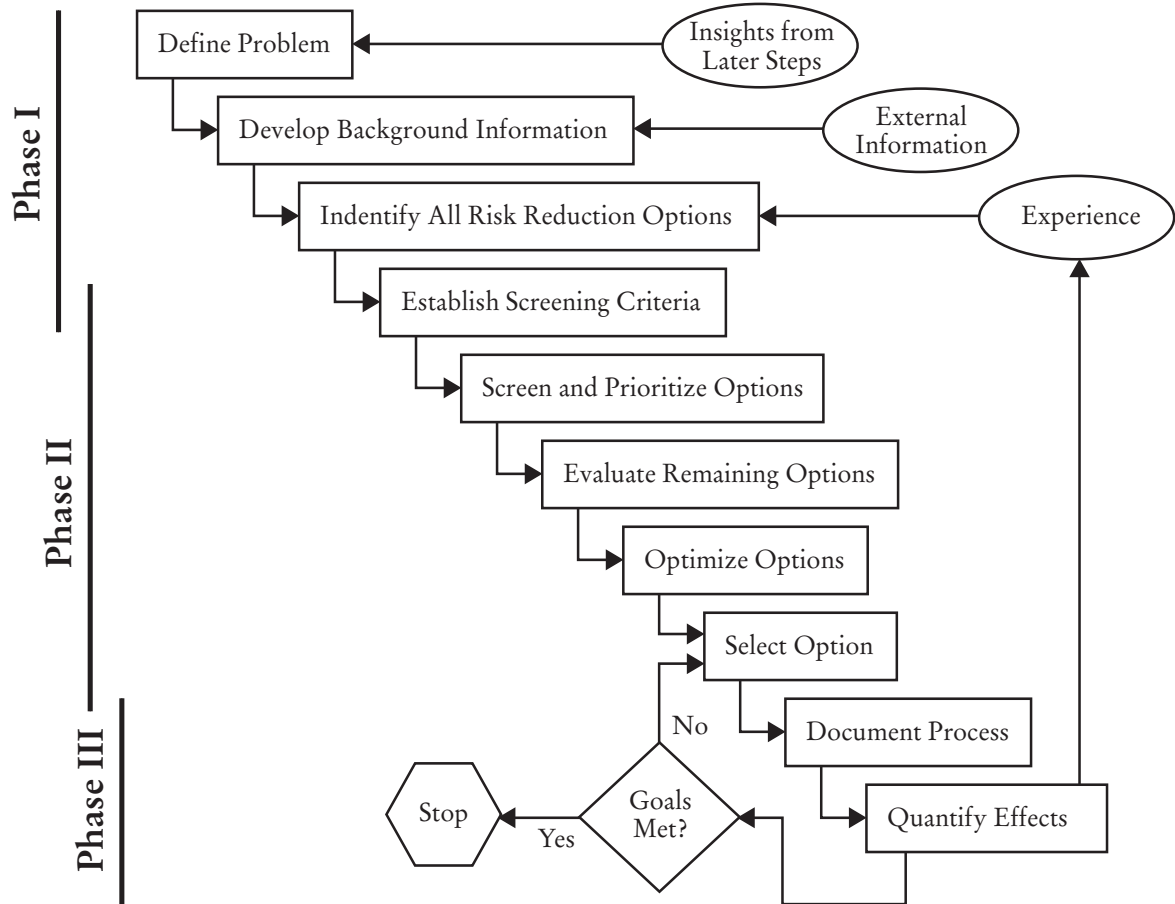
3.5.1 What We Have

The Risk Reduction Options Subcommittee (RROS) developed a process for identifying the most effective risk management approaches for a variety of types of risk problems that might confront a decision-maker. Specifically, they considered options analysis from three different perspectives: a) for a stressor-based problem (e.g., ozone); b) for a geographically based problem (e.g., risks associated with an urban area); and c) for a media-based problem (e.g., contaminated groundwater). Their efforts, which are outlined here, will be detailed in a separate SAB report.

In short, the RROS found that approaches for developing and evaluating options to reduce single risks are fairly well developed. However, the IED Framework emphasizes the importance of examining a broader array of potential options than might typically have been done in the past. Criteria should be developed to screen potential options, aggregate or disaggregate options, and, through an iterative process, converge on a set of options that analysis indicates would best meet the goals. As noted in the previous sections, analysis of the economic and societal consequences of various options is an important aspect of options analysis.

The results of the Subcommittee's deliberations on identifying, screening, and selecting risk reduction options, and the relationship of these steps to the phases of the IED Framework, are captured in the 10-step process depicted in Figure 6. The first step in the method is to define the problem. Articulation of the environmental problem(s), including specific goals for what/whose risk is to be reduced and by how much, is critical to subsequent steps. Clear environmental goals, with explicit statement of the relationships and the potential tradeoffs among goals, are the founda-

Figure 6. Risk Reduction Options Selection Methodology



tion from which objectives for the risk reduction program can be derived. In addition to information on the nature of the risks, other aspects of Problem Formulation that are particularly critical for the design of a risk reduction program include: a) statement of the desired state or goal in measurable terms; b) specification of methods for measuring improvements toward the goal; and c) identification of likely constraints on possible solutions. Constraints may include such things as

budget, time, jurisdictional authority, and legality of proposed options.

The remaining nine steps in the methodology cover development of background information, identification and screening of potential risk reduction options, selection of option(s) that best meet the screening and selection criteria, and documentation of the decision. There is an extensive decision analytic literature that presents methods (e.g., benefit-cost analysis, matrix qualitative

ranking, and multi-attribute decision procedures) that may be useful in the screening and selection process.

The RROS also analyzed seven different categories of options (as well as subcategories) (Table 2) and described situations in which they felt each category of options would be most effective and least effective.

3.5.2 What We Need

The task of developing and selecting risk reduction options is most easily envisioned in terms of reduction of a single risk, e.g., one associated with a particular stressor or source. Integrated environmental decision-making,

however, requires a more complex analysis of options. Although it is often best to address risks with a combination of risk reduction tools, this often is not done because of inadequate information on the multiple sources of a stressor and their relative contribution to total risk.

Extending the methodology to an integrated problem set containing risks from multiple stressors (e.g., those experienced by a particular community) will further increase the complexity of the analysis. Thus, it will be important to aggregate or disaggregate the problem set (e.g., using “root cause” or “common source/common pathway” analysis) so that analysis of risk reduction options is more manageable. Although it may not be possible to group all risks of concern on the basis of their technical attributes, a scientific analysis of the risks may well reveal commonalities that indicate which risks will be affected by the same risk reduction option.

The likely effect of this integrated view is that the option(s) selected to reduce a group of risks might differ from that which would be selected to reduce the top ranked risk, if it were to be considered in isolation. The complexity of the analysis also increases greatly as the number of screening and selection criteria increase.

One objective of options analysis in an integrated decision-making context might be to identify those options that may simultaneously reduce, directly or indirectly, risks posed by more than one stressor. Such analysis would be important if the management goal were to maximize the reduction of the total aggregate risk from multiple stressors, rather than to maximize the reduction of risks posed by any single stressor. This approach, requiring as it may the simultaneous consideration of risks from quite different types of stressors, has not yet been fully developed; and it will not be trivial to implement. Nevertheless, the SAB believes that its development and implementation offer tremendous potential for improving environmental health overall.

Table 2. Risk Reduction Option Categories Evaluated by the RROS

- 1. **Communication/Education**
 - a. Information Reporting
 - b. Technical Assistance
- 2. **Enforcement**
- 3. **Engineering**
- 4. **International and Intergovernmental Cooperation**
- 5. **Management Systems**
- 6. **Market Incentives**
 - a. Tradable Emissions
 - b. Pollution Charges
 - c. Subsidies
- 7. **Regulation**
 - a. Standards
 - (i) Harm-based
 - (ii) Technology-forcing
 - (iii) Design
 - b. Product Bans
 - c. Challenge Regulations

Examples of challenges inherent in applying options analysis to an integrated problem set, consisting of multiple stressors, sources, or endpoints, include the following:

- a) **Aggregation** is helpful in identifying multiple stressors that may have a common set of risk reduction options with the objective of selecting a set of options that will provide the most risk reduction for the set of risks being analyzed. Practically speaking, it will not be possible to optimize risk reduction over all stressors of concern considered at once. For this reason, screening and aggregation of stressors into manageable subsets should be driven by analysis of common aspects of stressors, root causes, and/or activities.
- b) In order to compare risk reduction across sets of options and sets of risks, and to evaluate risk reduction per unit cost, it is critical to have a **common measurement of risk or common denominator for all risks**. In many cases, comparisons of risks and risk reduction under different scenarios will involve unlike risks (e.g., cancer risk in humans vs. chronic health effects vs. effects on wildlife populations), even where those risks have a common “root cause” (e.g., a single stressor or source). While models can be developed to weight and combine the different attributes in disparate types of risk, getting wide-spread social agreement on such weightings may be quite difficult.
- c) **Uncertainty** associated with options analysis is likely to increase as a broader set of options and an array of stressors are considered simultaneously. Sources of this uncertainty include the relative contribution of different stressors/ sources to the total aggregate risk; the effectiveness of combined options for reducing aggregate risk; and the benefit-cost, equity, or other tradeoffs involved in addressing groups

of risks. The extent of uncertainty associated with a decision may affect the balance of options selected. When uncertainty is high, for example, it may be easier to gain support for education/communication or management system approaches rather than for regulation.

3.6 Performance Measures

In recent years there has been increased interest in tracking, measuring, and reporting on the performance of governmental actions. Most notably, the Government Performance and Results Act (GPRA) requires that federal agencies report annually on measures of the results of their various programs and activities. In addition, there has been discussion and activity in the area of “environmental report cards” as a mechanism for succinctly summarizing the state of the environment in easily comprehensible terms.

3.6.1 What We Have

To evaluate performance, one should have a good set of measures and a system for evaluating and reporting data on those measures.

In the area of measures, the SAB identified four types of performance measures that can be used in concert to evaluate progress toward environmental goals, whether broad goals that relate to a number of management and regulatory programs or specific goals defined for a particular integrated environmental decision:

- a) **Process Measures** are measures of administrative effort or program actions that are presumed to result in environmental or health improvements (e.g., number of permits issued, number of enforcement cases pursued, number of contaminated sites cleaned up to standards).
- b) **Stressor Measures (levels)** are measures (levels) of stressors in the environment used to

GPRA requires that federal agencies report annually on measures of the results of their various programs and activities.

determine attainment or non-attainment of desired reductions in stressor levels; e.g., total emissions of a pollutant, concentrations of particulates in ambient air, levels of dissolved oxygen or turbidity in a stream, and density of roads in a watershed.

- c) **Exposure Measures** are measures of the co-occurrence or contact between an individual or population and environmental stressor(s) over a defined time period. The term “exposure” is traditionally associated with chemical stressors (e.g., contaminant levels in food, concentrations of contaminants in tissues, time-activity measures, and total exposure to a contaminant via all routes), whereas the term co-occurrence is often used as a broader term applicable to chemical, physical, and biological stressors. Exposure measures are more directly related to effects than ambient levels of stressors in environmental media because they address direct contact with the stressor. These measures may also be more readily linked to risk management decisions than effects measures since causes of adverse effects are often multi-factorial and difficult to relate to a single environmental variable. The use of biological markers of exposure as a measure of environmental insults is a rapidly expanding field.
- d) **Effects Measures** are measures of human and/or ecological effects (e.g., asthma rates, deaths from acute poisoning from household products or pesticides, deaths from cancer, acres of wetlands gained or lost, local extinctions of important species) the changes in which can be used in one of two ways: (1) to assess the impact of an environmental risk reduction program; and/or (2) for **condition assessment**, in which a suite of effects measures are evaluated and reported in combination to characterize the health or condition of an entire population or ecosystem. Condition

assessment provides a baseline against which to evaluate the success of broad policies or multiple decisions impacting a population or geographic region.

Although it is difficult to relate changes in human health condition to a single environmental factor, recent studies are improving our ability to identify precursors to chronic diseases so that the detection of early effects occurs closer in time to the environmental exposure(s). Examples of precursor measures include changes in the P53 gene associated with exposure to sunlight (as an early marker of damage that may develop into skin cancer), changes in lung function associated with exposures to air pollutants, and changes in IQ associated with exposure to contaminants such as lead.

The Committee considers measures of effects or condition to be **environmental outcome measures**. We note that this definition differs from the Agency’s definition of “environmental outcomes,” which also includes measures of stressor levels (EPA, 1997b). We recommend, however, that stressor measures be kept distinct from environmental outcome measures because a) changes (increases or decreases) in stressor levels do not necessarily translate into changes (increases or decreases) in risk, and b) the public’s environmental goals are typically in terms of desired states of health or condition, rather than desired stressor levels.

The different types of measures can be thought of in terms of a spectrum of measures ranging from least directly to most directly related to actual environmental outcomes, which are of primary interest to the public. In many cases, the spectrum of measures will also correspond to a spectrum of response times, ranging from shorter term to longer term measures. For example, it is relatively quick and easy to document the number of permits issued in a year, but it is more difficult and time-consuming to determine the actual

Evaluating the Success of an Integrated Environmental Decision: A Watershed Example

To illustrate the use of each of the types of performance measures to report on a specific Integrated Environmental Decision, consider a watershed management or restoration program. In this example, the ultimate **goal** of the program is to maintain or re-establish an ecosystem that supports a diversity of habitat types along with their resident communities of plants and animals, supports essential ecological functions, and is self-sustaining. Here, the Integrated Environmental Decision will consist of a set of interrelated actions, many of which will be designed to address multiple stressors in order to achieve a reduction in the aggregate risk from those stressors. Other IED program actions will focus on restoring damage from past stressors (such as the restoration of riparian zones damaged by livestock operations in order to decrease sedimentation downstream, provide shade and cooler temperatures for aquatic species, and provide additional nutrients to the system from dropping leaves).

The evaluation criteria used to judge overall IED program results will include measures of habitat quality (such as length of intact corridors of natural riparian vegetation), water quality and temperature, hydrology that mimics natural variations, the extent of connectivity between floodplains and the river, nutrient balance, presence of sustainable native populations, and the like. Taken together, these **effects measures** effectively describe the **condition** of the watershed, i.e., whether the watershed, in fact, can sustainably support native populations and their habitats and maintain ecological functions — and they therefore report on the aggregate results of the IED program.

Each of these effects measures can also be used as to evaluate the success of individual actions within the IED program. Following the example above, measures of length of intact riparian corridor, water temperature, and nutrient balance would be used to assess the success of specific actions taken to restore riparian zones.

The time frame required to see changes in the effects measures will vary. Some, such as population levels of short-lived species of interest, may be detected after only one year of a management regime that alters pollutant inputs and water releases to the system. Other environmental responses may take more than ten years to be detectable.

In addition to the effects measures and condition assessment, direct reporting on the decreased pressure from various stressors will be useful. In the example above, such **stressor measures** might include the decrease in the rate of new riparian damage and increases in the release of cool water from dams in the summer. Stressor measures relating to other actions that are also part of the IED program might include reductions in ambient pollution levels, decreases in the number of unscreened pumps that injure fish, and the restoration of periodic flood flows.

Finally, **process measures** will provide insight into the level of effort expended and provide a shorter-term indicator that the program is proceeding as planned. Examples of process measures might include conservation easement contracts signed for the management of riparian corridors, changes in the regulations governing water releases from dams, and numbers of water pollution permits updated with new effluent limits.

An environmental results reporting system should include a mix of process, stressor, exposure, and outcome measures.

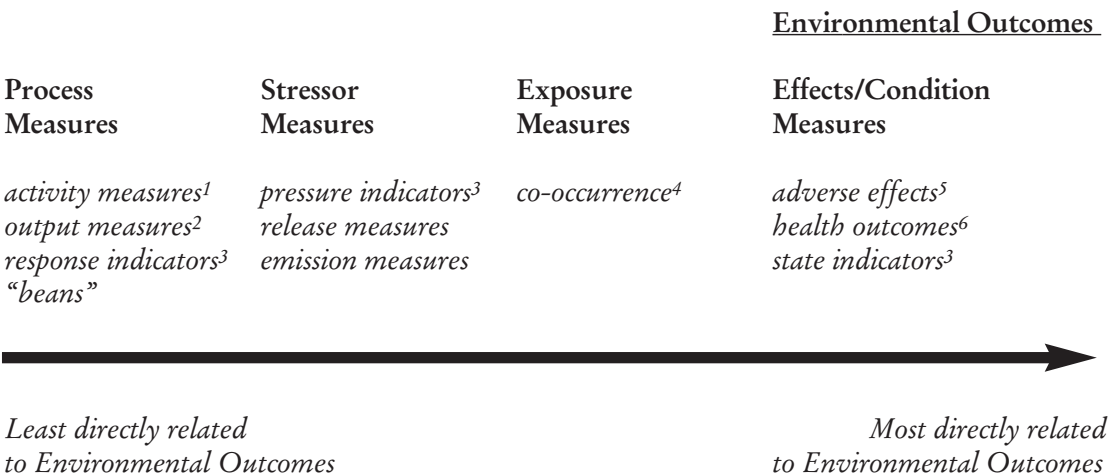
impact of that process measure on the condition of the environment. Figure 7 illustrates this spectrum and relates the Committee’s terminology to other commonly used terms for environmental performance measures.

In the area of reporting systems, the SAB recommends that feedback be provided on the extent and distribution of environmental risks to determine whether the relative seriousness of risks was accurately characterized in the first place and whether specific risks have changed as a result of an implemented risk reduction program. Report cards also should provide the basis for evaluating the performance of specific risk reduction programs or decisions, as judged against decision criteria such as efficacy at reducing aggregate risk, cost, equity, and time required to achieve risk reduction goals. In summary, environmental report cards should provide the information

needed to a) identify opportunities for course correction and adaptive management, i.e., modification of risk reduction approaches in light of performance information or new information on risks; and b) assign specific accountability—to individuals, programs, or organizations—for environmental results.

Report cards for evaluating integrated environmental decisions should contain specific milestones that can be used to measure progress towards achieving the environmental goal(s) agreed upon by the participants. Each of the selected endpoints defined during Problem Formulation (Phase I) should be a part of the report card, as well as the specific measures or indicators that are monitored to characterize those endpoints. The frequency of the reporting should be commensurate with the nature of the risk and the expected time frame for system response.

Figure 7. Spectrum of Performance Measures



¹EPA, 1997b; ²GPRA; ³OECD, 1998; ⁴ERS Method; ⁵EPA, 1998; ⁶NRC, 1996

3.6.2 What We Need

Progress is being made in the area of environmental report cards. For example, there is an effort underway, initiated by the Office of Science and Technology Policy and jointly funded by eight federal agencies, to design a national environmental report card. This multi-year project, which is being conducted by the Heinz Center, has already produced a prototype design for a report card on the state of the nation's ecosystems and specific indicators of ecosystem condition for 3 types of ecological systems: coastal/ocean, croplands, and forest systems (Heinz Center, 1999). Over the next several years, the Heinz Center plans to develop a list of indicators for an additional 3 types of systems: freshwater, arid lands/rangelands, and cities/suburbs. Although the SAB has not reviewed the appropriateness of the report card design or the specific proposed measures, the effort is a clear indication of growing federal agency interest in environmental report cards. A somewhat analogous reporting effort that focuses on human health is Healthy People 2000—and now Healthy People 2010—which defined a series of health objectives and established a series of health indicators that are monitored and reported annually (e.g., see National Center for Health Statistics, 1999).

An environmental results reporting system should include a mix of process, stressor, exposure, and outcome measures. Historically, the Agency has focused primarily on process and stressor measures. Therefore, more emphasis should be given to outcome measures, developing new ones where required. Environmental outcome measures—whether of health, ecological condition, or quality of life—may not exist, may be subtle or difficult to measure, or may be observable only over long time frames. Evaluating the performance of risk prevention programs may be particularly problematic. Thus, process, stressor, and exposure measures will continue to be important in environ-

mental decision-making and management. Outcome measures, however, are an important means of verifying the theoretical basis for the control or abatement options chosen. In other words, if the postulated relationship between stressors and effects is inaccurate, then stressor or exposure reductions might not produce the expected improvements in adverse effects or condition.

Decisions on the design of a report card system have implications for information collection systems, both those that track administrative processes and those that collect environmental data (e.g., ambient monitoring programs). In selecting performance measures, there will often be a gap between what it would be desirable to know and what it may be feasible to know. This gap may exist as a result of several factors, including the limited state of knowledge about the relationship between stressors and effects, the costs involved in obtaining certain types of information, and the willingness of affected people to provide information. Nonetheless, it is important that careful consideration of the most desirable performance measures, including those based on an established chain from process and stressor measures to exposure and outcome measures, influence the types of information that are actually collected.

The need for data to assess performance of integrated environmental decisions emphasizes again the importance of monitoring programs that can measure both ecological and human health exposure and outcomes. Implementation of a reporting system for human health risk reduction will be hampered in many cases by a lack of data in key areas; e.g., exposures, differential susceptibilities among subpopulations, and incidence of non-fatal diseases. In the ecological arena, assessments of ecological integrity require information not only on water quality, air quality, soil quality, water flow, and populations of certain species, which are commonly monitored today, but also measurements of biological community structure,

...the design of a report card system has implications for information collection systems, both those that track administrative processes and those that collect environmental data...

the presence of successional states, diversity of habitat types across the landscape, connectivity, altered topography, hydrodynamic patterns, and so forth. This latter set of parameters is not typically monitored by EPA, but has received greater attention by other federal agencies (e.g., USGS, USFS). This fact emphasizes the importance of strengthening and maintaining the collaboration among the many agencies that conduct monitoring, an effort begun several years ago under the auspices of the Committee on Environment and Natural Resources (CENR, 1997).

Even the Agency's traditional list of process measures will need to be expanded in order to evaluate the performance of some of the new approaches to environmental management. In recent years, the Agency has added more tools to the environmental toolbox, bringing to bear such new approaches as economic incentives, negotiated agreements, and the like. Therefore, the collection of data to evaluate these new

approaches should evolve as well. There are several important inputs currently missing from most reporting systems that would provide valuable information for assessing how well environmental programs have worked and what changes or adjustments might be made. In the case of a marketable permit system, for example, systematic reporting about the number of transactions, the average price per unit of the traded commodity, the number of market participants, the net reduction in pollution output, and average marginal cost per unit of pollution reduced should be compared with initial predictions. To the extent that a risk management program involves more than one tool, the entire panoply of actions should be reviewed for efficacy, cost, and other measures of performance. Separate information should also be provided on the "non-quantitative" inputs to decision-making, including the effects of the risk reduction program on sustainability and equity.

4. RECOMMENDATIONS TO THE AGENCY

As a result of conducting the Integrated Risk Project, the SAB has developed a set of 10 recommendations that should help the Agency take “the next step” in improving environmental decision-making in this country.

Recommendation 1: EPA should continue development of integrated, outcomes-based environmental protection, while maintaining the safeguards afforded by the current system.

Previous environmental management approaches, both regulatory and non-regulatory, have resulted in substantial improvements in human health and ecological condition, particularly in regard to chemical risks. While maintaining the current regulatory and management structure, the Agency should continue its development of more broadly integrated approaches to environmental decision-making. In particular, the Agency should use the concepts inherent in the Framework laid out in this report to seek opportunities for going beyond current protections by taking a truly integrated look at risks, opportunities for risk reduction, and the consequences of addressing (or failing to address) those risks. To the degree possible, the focus of this next step of environmental decision-making should be on environmental results; that is, on demonstrable outcomes (improvements) in the environment resulting from integrated action. As a part of this effort, the Agency will need to develop additional tools to implement the approach and to monitor the results of actions taken.

Recommendation 2: Because science plays a critical role in protecting the environment, EPA should commit the resources necessary to expand the scientific foundation for integrated decision-making and outcomes-based environmental management.

An important theme of the IED Framework is the need to integrate scientific and technical information on risks and risk reduction opportunities with information on societal values, aspirations, and goals. The call for greater inclusion of multiple disciplines and points of view, however, must not obscure the fact that science and scientific methods are critical to sound environmental decision-making. Science has a unique and critical role to play in protection of the environment. It is through scientific investigations that many environmental problems are first discovered; e.g., the depletion of stratospheric ozone, hypotheses about environmental endocrine disruptors. Science also is instrumental in developing, testing, and evaluating risk reduction options, and social sciences offer techniques for assessing societal preferences and wants. Implementation of the IED Framework, particularly its application to multiple-stressor problems, will in many cases require new science, both empirical and theoretical. In order to gain the greatest benefit from this next step in environmental decision-making, the Agency will need to invest in research designed to support integrated risk assessment and management.

Recommendations to Foster Integrated Environmental Decision-making

1. EPA should continue development of integrated, outcomes-based environmental protection, while maintaining the safeguards afforded by the current system.
2. Because science plays a critical role in protecting the environment, EPA should commit the resources necessary to expand the scientific foundation for integrated decision-making and outcomes-based environmental management.
3. EPA should apply and encourage the broader use of risk comparison methodologies that clearly identify how scientific information and judgment are incorporated into risk comparisons.
4. EPA should explore a broader range of risk reduction options in combination to manage environmental risks.
5. When evaluating risk reduction options, EPA should strive to weigh the full range of advantages and disadvantages, both those measured in dollars as costs and benefits and those for which there may not be a comprehensive dollar measure, such as sustainability and equity.
6. EPA should seek and develop methods to characterize public values and incorporate those values into goal-setting and decision-making.
7. EPA, by itself and in concert with others, should identify, collect, and disseminate scientifically-based environmental metrics organized in new ways to support a more integrated approach to managing environmental risk.
8. EPA, by itself and in concert with others, should develop a system of “report cards” to organize and disseminate information on the status of ecological and human health and the quality of life in order to assess the effectiveness of its environmental decisions and to guide future environmental management.
9. EPA should expand and develop new collaborative working relationships with other federal and non-federal governmental agencies and others who also will be involved in integrated environmental decision-making.
10. EPA should explore options for reducing risks from significant stressors that currently are addressed inadequately by the nation’s environmental institutions.

Recommendation 3: EPA should apply and encourage the broader use of risk comparison methodologies that clearly identify how scientific information and judgment are incorporated into risk comparisons.

Scientific information on risk, such as quantified risk assessments and scientifically demonstrated relationships between stressors and effects, provides an essential basis for making objective risk comparisons. However, desired scientific information often is incomplete or absent, and scientists have to use their best professional judgment to bridge important gaps in the data. Further, scientific information and analyses, by themselves, are not sufficient for comparing unlike risks; e.g., when comparing human health risks vs. ecosystem risks or cancer risk in adults vs. neurologic risk to children. Thus, public values also must come into play in making the comparisons. For these reasons, methodologies used to compare environmental risks—whether human health risks, ecosystem risks, or both—should incorporate not only the most up-to-date scientific information, but also should identify explicitly where professional judgment and values have influenced the results. In the course of this project the SAB developed, to varying extents, two prototype methodologies for risk ratings by technical experts. These and similar approaches should be further explored as possible points of departure for the Agency as it seeks to develop and use methods for comparing relative environmental risks that incorporate public values.

Recommendation 4: EPA should explore a broader range of risk reduction options in combination to manage environmental risks.

In 1990, the SAB recommended in *Reducing Risk* that the nation make greater use of all the

tools, including market forces, information, and product specifications, available to reduce risk. Now, almost a decade later, many of those tools are being used to a greater extent than ever before. The challenge for EPA is not only to expand the use of those various tools, but also to use them in creative, coordinated ways to reduce multiple risks to multiple receptors in communities and ecosystems across the country. In the course of this project, the SAB described a prototype methodology for identifying and selecting risk reduction options to address single or multiple stressors. This methodology should be evaluated by the Agency as a possible approach for better identifying multidimensional strategies to control complex environmental problems that involve many sources, stressors, and receptors.

Recommendation 5: When evaluating risk reduction options, EPA should strive to weigh the full range of advantages and disadvantages, both those measured in dollars as costs and benefits and those for which there may not be a comprehensive dollar measure, such as sustainability and equity.

The benefit-cost paradigm that underlies many environmental decisions is the simple formulation of whether the gains that accrue from protective actions are worth what is given up to attain them. There is a subsidiary question: Would other possible actions be preferable? This question highlights the importance of taking all effects, including long-term effects, into account. It also raises the sometimes hidden issue of how people value different aspects of the environment. Some of society's environmental values can be measured directly in monetizable terms, and others can be inferred and translated into monetizable terms with some confidence. But other things that people value, such as sustainability and equity, often may be expressed only qualitatively, yet are

of no less importance. As a part of this project, the SAB has described the applicability and limitations of the benefit-cost approach, and suggested areas where new approaches to characterizing values are essential. The SAB also has attempted to define better the full range of relevant questions that must be considered in environmental valuation.

Recommendation 6: EPA should seek and develop methods to characterize public values and incorporate those values into goal-setting and decision-making.

Community and national values have been and will continue to be a primary driver of community-level and national efforts to protect the environment. However, values usually are not weighed transparently in the decision-making process. Rather, they usually are implicit in the judgments made by decision-makers. Thus, they often influence decisions in ways that are not clear to, or reviewable by, the public.

Because public values undoubtedly help shape environmental decisions, it is important to understand and document their role in and influence on decision-making. It is also important to elicit public values systematically, differentiate values from technical information as a part of decision-making, and include their effects on decisions as part of the public record. In this way, value judgments will be neither disregarded nor disguised. Individual and community values should be solicited systematically by social scientists and other appropriately trained individuals. The deliberative processes that are used in arriving at decisions should involve professionals trained in fields like consensus-building and dispute resolution. EPA should make more extensive use of experts in the areas of behavioral and decision science so that a more complete representation of community values is incorporated into the Agency's decisions. Research likely will be necessary to develop improved methods for helping people develop

considered values and for eliciting and using public values in decision-making.

Recommendation 7: EPA, by itself and in concert with others, should collect and disseminate scientifically based environmental metrics to support a more integrated approach to managing environmental risks.

The transition to and effectiveness of integrated environmental protection will depend to a large extent on the availability and utilization of appropriate information in the areas of exposure, human health, ecological health, and quality of life. Current information collection efforts, however, often are insufficient, inadequately organized, or focused on inappropriate endpoints. In the area of human health, for example, data on non-fatal outcomes of environmental exposures, such as asthma, are not being collected except in a rudimentary manner or at certain sites. Only mortality information is collected systematically at all locations and can be related to some limited information on selected exposures. With regard to ecological data, more comprehensive information is needed on the current status of ecosystems such as wetlands, lakes, forests, and grasslands. This information should include the extent to which each ecosystem is exposed to and affected by non-chemical stressors such as habitat conversion, habitat fragmentation, and invasions of exotic species.

The challenge facing EPA and the nation is not only one of collecting the right environmental data, but of finding new ways to manage and use those data. Working with other federal and state agencies, EPA should take a leadership role in identifying critical environmental data gaps, including data on exposures and health and ecological outcomes; integrating the largely fragmented data collection efforts already underway; and disseminating integrated environmental information to decision-makers and the public.

Recommendation 8: EPA, by itself and in concert with others, should develop a system of “report cards” to organize and disseminate information on the status of ecological and human health and the quality of life in order to assess the effectiveness of its environmental decisions and to guide future environmental management.

One of the most valuable uses of environmental data is to measure the results of the actions society takes to reduce environmental risk. However, even if such data did exist, through a vigorous implementation of Recommendation 7, there would still be a need to develop widely accepted and commonly used methods for evaluating a) the state of our environment and b) the success of national environmental protection efforts — where, over the long term, success is measured in terms of demonstrable outcomes in the health of humans and ecosystems.

Reporting on measures of progress towards ecological, human health, and quality of life goals will provide a number of benefits. First, the exercise of defining performance measures and reporting on them will bring more focus and discipline to the Agency by expressing the relationship between investments (measured in time, money, or information) and environmental results. Second, shorter term measures of progress (including process measures or measures of stressor reductions) will be useful for accountability and course correction. Third, longer term measures of progress (such as improvements in overall human and ecosystem health and quality of life) will be most helpful in determining whether goals are being met, whether further actions are needed to control well-recognized stressors, or whether new actions are needed to control new stressors.

To strengthen their credibility and utility, environmental report cards should contain informa-

tion derived from objective measurements, be transparent and clearly documented, and provide integrated information on progress towards multiple inter-related environmental goals.

Recommendation 9: EPA should expand and develop new collaborative working relationships with other federal and non-federal governmental agencies and others who also will be involved in integrated environmental decision-making.

Inherent in integrated decision-making is the idea that problem formulation and decision-making must match in scale and location. In some cases, decisions may be most effective when local or state governments play the primary role. In others, coordinated action across several levels of government or among a number of state and/or local governments will be required. In still others, national decision-making may be the preferred approach. In any event, integrated thinking about environmental problems will tend to drive decision-making to the agency or level of government where decisions are most appropriately made. As a consequence, EPA’s role will evolve to one in which the depth of control gives way to broader involvement in partnership with other agencies. EPA will continue to be responsible for implementing and enforcing federal environmental laws and statutes, conducting environmental research and development, and conducting stressor-specific risk assessments. At the same time, the Agency can exert national leadership to bring together appropriate agencies and stakeholders to explore integrated approaches to environmental problems.

Recommendation 10: EPA should explore options for reducing risks from significant stressors that currently are addressed inadequately by the nation’s environmental institutions.

Over the course of the Integrated Risk Project, it became clear to the SAB that a number of important human health and ecological risks are not being addressed adequately by the nation's environmental institutions. In many cases this is because risk management responsibility is not clearly assigned to any one government entity, or is scattered over many agencies and/or levels of government. This fragmented approach results in uncoordinated and incomplete efforts to identify cause-and-effect linkages and to manage risks. With regard to ecological risks, the SAB has concluded that many of the highest ranking risks (e.g., hydrologic alterations, harvesting of living marine resources, habitat conversion, climate change, and introduction of exotic species) are associated with physical and biological, rather than chemical, stressors, which do not fall clearly

within the purview of any single federal Agency. Important human health risks that remain unaddressed include those for which the environmental exposure link is suspected but not certain (e.g., asthma, brain cancer, and non-Hodgkins lymphoma) and risks associated with susceptible and/or compromised human populations.

To control many of these inadequately addressed risks will require the kind of integrated decision-making envisioned in this report. It will also require a new kind of integrated institutional leadership. When EPA determines that serious risks are not being addressed effectively by existing environmental institutions or decision-making systems, the Agency has a responsibility to inform the public about those risks and bring together the appropriate federal, state, and local agencies to address them.

5. LESSONS LEARNED

The Integrated Risk Project (IRP) has been unlike any other project undertaken by the SAB. Conceived by some as a simple updating to the 1990 *Reducing Risk* report, it soon became evident that the IRP was far more complex and far more difficult than earlier undertakings. Issues of science (e.g., risk assessment, cumulative risk, and economics) merged with even less tractable — but arguably even more important — issues of social sciences and ethics (e.g., personal and group choice, trans-generational equity, and the role of government vis a vis the public). More than 50 participants from various fields of science and social science worked together to share their respective experiences and insights in a collaborative effort to illuminate a path that would lead to “the answer”. In the process, the participants gained a new appreciation for the benefits from and the barriers to interdisciplinary efforts of this sort. Differences in background, nomenclature, and academic culture of the participants both enhanced and hindered progress.

Recent advances in science and technology legitimize asking some of the “tough questions” that were necessarily simplified just a few years ago. Questions of total cumulative risk of multiple endpoints, from multiple pollutants, from multiple sources, by multiple routes of exposure are now being confronted directly. More powerful methods of data collection and analysis, more comprehensive models, and broader consideration of management options are evidence of the growing scientific support for a more integrated approach to environmental decision-making. Inclusion of interested and affected parties in addressing environmental

problems, the emphasis on an iterative analytical/deliberative process, and continual grappling with the ethical aspects of decision-making (e.g., the meanings of “values”, the uneven distribution of benefits and costs, and explicit consideration of effects on future generations) point to a recognition of the fact that today’s problems include important aspects that must be addressed by social sciences and ethics.

It is important to recognize that successful application of the IED Framework will require some adjustments in the manner and degree to which the many participants interact over the course of the decision-making process. Integrated environmental decision-making requires the sharing of information, ideas, approaches, and management deliberations to a degree now seldom practiced among individuals of very different backgrounds. Although this sharing is a positive aspect of the Framework, it may require significant adaptation on the part of individual policy-makers and institutions. For example, decision-makers will need to interact more extensively with scientific and technical analysts and the public in the course of developing integrated approaches to environmental risks. Likewise, scientific and technical experts will need to recognize the role (and limitations) of science in decision-making, and also to recognize the legitimate role of values in establishing environmental goals and selecting management approaches. This culture change will be assisted by familiarity and experience with integrated environmental decision-making. Experience, combined with discipline, will also be needed to apply the Framework with discretion to the depth of detail

necessary for a particular problem, and no more; i.e., the Framework should not become a barrier to decision-making.

Additional challenges likely to be encountered when applying the Framework include the following:

- a) Problems of understanding arising from differences in terminology and outlook imbedded in the different disciplines and backgrounds of the participants in the process;
- b) Difficulties of using both qualitative and quantitative measures concurrently in the decision process;
- c) The need to compare different types of risks (e.g., health, ecological and quality of life risks) within a common decision framework and to discern and define the inter-relationships among risks so as to define common goals across the different risk types; and
- d) Time-lags between implementation of risk reduction plans and the detection of results

and effects, which make the selection of appropriate performance measures particularly important.

In some ways, the Board has been true to the old adage that “One’s goal should exceed one’s grasp.” That is, the goal of this project — to articulate a complete and rational method for including all aspects of integrated environmental decision-making in a single process — has exceeded the SAB’s grasp. In fact, it is likely that that goal will never be reached to everyone’s satisfaction. And yet, the Framework for Integrated Environmental Decision-making that was developed during the course of the project clearly points to the direction in which “the next step” of environmental decision-making should go. The efforts of the individual Subcommittees can be examined for further insights about how the Agency might — or might not — make additional progress in that direction. In any event, there is enough direction and more than enough challenge in this report to keep the Agency — and others interested in the next step of environmental decision-making — productively active for some time to come.

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